Preventive Medicine Reports 59 (2025) 103270

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Standardisation of bioimpedance assessment in young children: a feasibility study of home-based body composition measurement in Danish two-year-olds

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ARTICLE INFO

Keywords:
Body composition
infant
paediatric obesity
anthropometry
bioelectrical impedance
Feasibility studies
Nurses, community health

ABSTRACT

Objective: Body composition takes a key position in monitoring obesity risk in children. Bioelectrical impedance analysis (BIA) offers a promising, non-invasive method, suitable for field use and young children. However, existing BIA protocols are not tailored to this age group, leaving a knowledge gap on procedures feasible and acceptable to children, parents, and health professionals. This study aimed to develop and assess the feasibility of implementing a standardised protocol for BIA measurements in young children.

Methods: The settings of community health nurses (CHNs) in Denmark were used to develop a standardised protocol for BIA measurements of two-year-old children (January 2022–March 2025). Feasibility was evaluated in a community-based sample of 72 children, evaluating suitability, practicality, adaptation, resources, and acceptability.

Results: The BIA protocol was developed through an iterative process exploring the children's reactions and cooperation during assessments. The final protocol was tested on 70 children (mean age 24.21 ± 1.21 months). A total of 50 children (71 %) completed the BIA measurements. CHNs reported the procedures as feasible, though challenges included child cooperation, equipment availability, and technical difficulties. Most parents (96 %) found procedures acceptable, and 79 % perceived their child accepted them.

Conclusions: This first study to develop and test a standardised BIA protocol tailored young children, demonstrates feasibility in home settings and high acceptability among parents, children, and CHNs. Although no normative BIA data exists for young children, our findings support the potential for integrating body composition monitoring into community-based early obesity prevention programmes, conditioning developmentally appropriate assessment and training health professionals.

1. Introduction

Childhood overweight and obesity remain major public health problems worldwide being associated with increased risk of physical and mental health problems in older ages (Zhang et al., 2024; Geserick et al., 2018). The poor prognosis of childhood obesity calls for strategies to break developmental trajectories of overweight, highlighting the need for early identification and intervention (Reilly et al., 2017).

Obesity risk in children is commonly measured using body mass index (BMI) or BMI standard deviation score as proxy indicators of body fat. However, in young children these measures have limitations in distinguishing between fat mass and fat-free mass (Freedman and Sherry, 2009; Wright et al., 2022), and direct measurements of fat mass and fat-free mass have been suggested (Wells and Fewtrell, 2008). Among the various methods available, underwater weighing (densitometry), dual-energy X-ray absorptiometry (DXA), magnetic resonance imaging, and air displacement plethysmography (ADP) are established reference methods for body composition assessment, with DXA widely regarded as the clinical gold standard (Fields et al., 2002; Ward, 2018; Heymsfield, 2005). However, these methods have several limitations,

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https://doi.org/10.1016/j.pmedr.2025.103270
Received 26 June 2025; Received in revised form 30 September 2025; Accepted 2 October 2025
Available online 8 October 2025
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including high cost, limited accessibility, time consumption, and the need for trained personnel (Fields et al., 2002; Ward, 2018; Heymsfield, 2005).

Bioelectrical impedance analysis (BIA) is increasingly used for measurement of fat mass and fat-free mass as it is non-invasive, portable, quick, and easy to use (Ward, 2019). BIA is not considered a reference method and there are no normative data for BIA-derived body composition in young children. Furthermore, normative data in young children are only available from accepted reference methods such as DXA, ADP, and four-compartment models (Lyons-Reid et al., 2024; International Atomic Energy Agency (IAEA), 2013; Hills et al., 2024; Butte et al., 2000; Wells, 2014), but these values cannot be directly applied to BIA. Despite these limitations, BIA is considered one of the few tools suitable for young children and a practical tool suitable for field and routine clinical use (Gallagher et al., 2020; Ward et al., 2013; Lyons-Reid et al., 2021a; Orsso et al., 2022). In this context, BIA assessments conducted in home settings may be particularly valuable in young children, as they may improve compliance and reduce logistical burden (Appelhans et al., 2016).

Existing BIA guidelines are primarily designed for older populations and do not account for the needs of young children (Orsso et al., 2022; Brantlov et al., 2017a; Lyons-Reid et al., 2020), being highly determined by the developmental stage of cognitive functions and emotional and behavioural regulation. This limits the quality, reproducibility, and comparability of BIA measurements in both research and clinical practice.

To address the knowledge gap on feasible approaches to BIA measurements in young children, the present study aims to develop and test a standardised and developmentally appropriate BIA protocol, using community health nurses' home-visits to 24-month-old children as the study settings. The aim was to evaluate the feasibility of implementing this protocol to improve early body composition assessment and contribute to the knowledge on feasible measurements in the field of early obesity prevention and research.

2. Methods

2.1. Study design and settings

The study was conducted in two phases. In the first phase, pilot testing was used to develop a protocol for home-based BIA measurement in young children while the second phase evaluated its feasibility.

2.1.1. BIA measurement procedures

Bioimpedance was assessed using the SFB7 lead-type device (ImpediMed, Brisbane, Australia). During a measurement, a weak, imperceptible and harmless electric current is passed through the body using surface electrodes placed at the base of the toes and fingers, with impedance measured with electrodes located at the wrist and ankle as the current travels through the body's tissues (Matthie, 2008). The SFB7 device weighs one kg and is transported in a protective suitcase. Further details are described in Supplementary 1.

2.1.2. Phase 1: developing a protocol for BIA measurements in young children

Six families with two-year-old children volunteered for the pilot test. Two community health nurses (CHNs) recruited the families from the general population in Denmark. The CHNs participated in developing the BIA measurement protocol and performed the pilot tests. All participating children were healthy with no developmental or behavioural difficulties.

The CHNs received two hours of practical and theoretical training. ImpediMed's standard measurement guide for the SFB7 device (ImpediMed, 2009) was used as a reference for a preliminary setup. This guideline recommends fasting, normal hydration, avoidance of intense physical activity, and voiding before measurement. These factors were considered unachievable or unethical in young children and thus disregarded (Brantlov et al., 2017a).

The preliminary setup was tested on two two-year-old children to identify the main processes and challenges. Neither completed the testing procedures. Field notes from CHNs highlighted challenges: (Zhang et al., 2024) getting children to lie supine, (Geserick et al., 2018) resistance to alcohol swabs due to the cold sensation and smell, and (Reilly et al., 2017) anxiety about the leads' alligator clips. These challenges were discussed in research team meetings with bioimpedance experts and clinicians, and critical factors influencing BIA measurements were reviewed based on existing literature (Brantlov et al., 2017a; Lyons-Reid et al., 2020; Lyons-Reid et al., 2021b).

Protocol adjustments were made and tested again on two additional two-year-old children. CHNs tried to distract the children with videos and snacks, but cooperation remained difficult, and only one measurement was completed. An alternative bioimpedance measurement tool, the SOZO device from ImpediMed, was tested as it allows patients to stand and is lead-free. However, it was not portable, and the children were unable to reach the handles.

Based on the findings from the four pilot tests, the protocol was revised to remove non-critical factors and include strategies to improve child cooperation, such as allowing the child to sit on their parent's lap, and children could choose cartoon stickers to attach to the electrodes. Parents received detailed information about the procedures, both in written and oral form, and CHNs underwent additional training to implement the revised protocol. The revised protocol was tested on two more children, both successfully completed. CHNs reported that the revised protocol improved feasibility and mitigated the previous challenges (see Fig. 1).

A final standardised measurement protocol was developed for evaluation in phase 2, the feasibility study (Figs. 1 and 2).

2.1.3. Phase 2: Feasibility study

The feasibility study sample was drawn from a case in cohort sample of 486 children who were assessed at 24 months of age as a part of the Infant Health Study and a sub-study of feeding, eating, and weight development during the first two years of life (Skovgaard et al., 2022). Children were included based on the specific municipalities covered by the participating CHNs. The 24-month assessments were conducted by CHNs in the child's home, with the parents present, and included measurements of the child's weight, length, and BIA (Skovgaard et al., 2022). Infants with significant mental or physical disabilities requiring specialised treatment or care, as well as those whose parents did not speak or understand Danish or English, were excluded.

Five specific CHNs conducted the home-based BIA measurements. They had worked as CHNs for an average of 13.8 years but had no prior experience with body composition assessment.

Our target sample size was 50 BIA measurements, corresponding to 10 % of all follow-up assessments, and the measurements were conducted across ten municipalities between January 2022 and March 2025.

2.1.4. Practical procedures

All five CHNs were part of the feasibility study. They received three hours of practical and theoretical training in BIA to ensure valid and reliable measurements. The CHNs shared two BIA devices, and the measurement protocol was attached to each device. Dual-tab electrodes ensured reproducible placement at consistent anatomical landmarks. Parents were informed at least two weeks in advance about the home visit, allowing them time to consider their child's participation. They were informed in detail about the procedures, emphasising that the BIA measurement is painless and has no side effects. Parents could withdraw from the study at any time. During the home visit, the CHN started with measuring BIA and then assessed weight and length by standardised procedures. Recumbent length was measured to the nearest 0.1 cm using Seca 210 infant and toddler measuring mats, while weight was

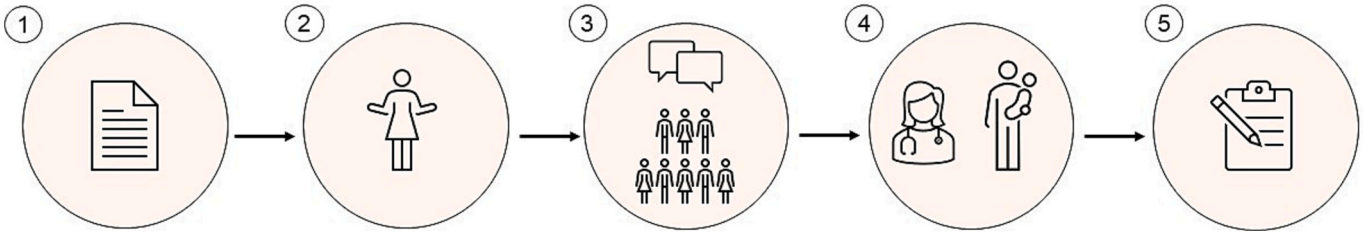


Fig. 1. Summary of the study procedures for developing a standardised protocol for home-based bioelectrical impedance analysis (BIA) in young children in Denmark (January 2022–March 2025). 1) The manufacturer's standard protocol was used as a reference for a preliminary setup. 2) The first pilot test revealed that the preliminary setup was unsuitable for young children. 3) Field notes, research team discussions, expert insights, and previous studies helped to identify alternative approaches, and the bioelectrical impedance analysis (BIA) measurement protocol was refined. 4) A second pilot test was conducted, and the revised protocol improved feasibility. 5) The feasibility of the final version of the standardised measurement protocol is tested in this study.

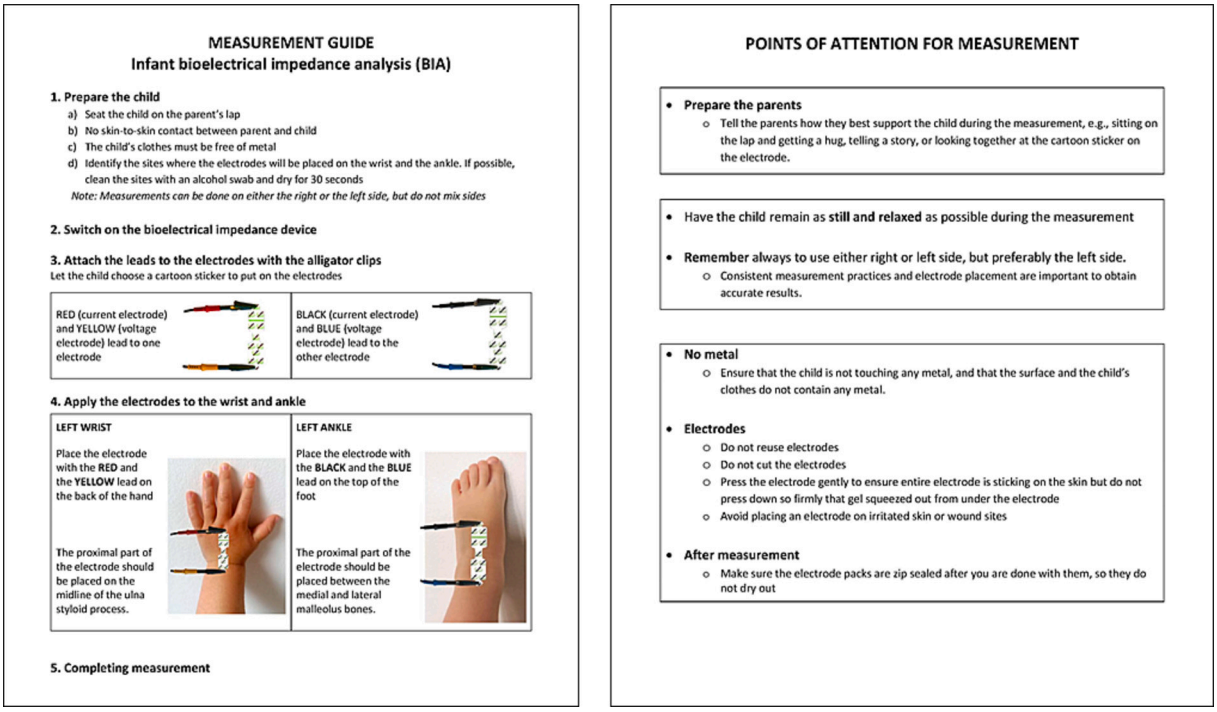


Fig. 2. Final standardised protocol to guide measuring bioelectrical impedance analysis (BIA) in young children, including front (Fig. 2a) and back (Fig. 2b) pages with step-by-step instructions for health professionals in Denmark (January 2022–March 2025).

measured to the nearest 0.1 g using calibrated Seca 878 scales. Children were not forced to complete measurements but were given a small gift for participation.

2.1.5. *Feasibility measures*

The present study adheres to the recommendations for a feasibility study outlined by Orsmond et al. and Bowen et al., which guide researchers in designing feasibility studies that emphasise process evaluation and preparation for larger-scale testing (Orsmond and Cohn, 2015; Bowen et al., 2009). Specifically, this study assessed the feasibility of conducting BIA measurements on children in home settings by addressing the following constructs: (Zhang et al., 2024) the suitability, including completion rate, barriers, and technical challenges; (Geserick et al., 2018) the practicality, including usability, burden, logistical challenges, and data collection procedures; (Reilly et al., 2017) the adaptation, including integration in home settings and healthcare services; (Freedman and Sherry, 2009) the resources needed, including training requirements and equipment availability; and (Wright et al., 2022) the acceptability by both parents and children (Table 1).

Feasibility data were collected by tracking registration of each measurement in an online survey database (REDCap). All five CHNs completed a structured survey assessing the feasibility of conducting BIA measurements in young children (Supplementary 2). After each completed and non-completed measurement, both the parent and the CHN received a feedback questionnaire (Supplementary 3). Notably, the questions addressing parental and child acceptability were introduced midway through the study, in 2023, as we decided to explore this aspect more systematically.

2.2. *Ethics approval and consent to participate*

The study was approved by the Research Ethics Committee of the University of Southern Denmark, in 2020, case no. 20/61404, and by the Committees on Health Research Ethics in the Capital Region of Denmark, in 2024, journal no. H-24049295. The CHNs informed parents about the collaboration between the municipality and the National Institute of Public Health, which allows contact with families using information from the health services. Parents received written information as part of an electronic invitation sent to their secure digital mailbox (*e-Boks*), a national system used in Denmark for official communication. For those without access to *e-Boks*, the information was sent by regular mail. Participation was entirely voluntary.

Table 1
Evaluation domains applied in the current feasibility study of measuring home-based bioelectrical impedance analysis (BIA) in young children in Denmark (January 2022–March 2025).

Feasibility domain	Definitions according to Bowen and Orsmond (Orsmond and Cohn, 2015; Bowen et al., 2009)	Outcomes of interest	Main questions	Methods
Suitability	Refers to how appropriate or fitting BIA is for assessing children in a home setting.	Completion Rate	How many completed the measurement?	Tracking registration
		Barriers	What are the reasons for refusal or unfulfilled measures?	Tracking registration Community health nurse (CHN) feedback
		Technical Challenges	Were there any technical challenges?	CHN feedback
Practicality	Evaluating whether BIA can be realistically and efficiently carried out in a home environment.	Usability and Ease of Use	How easy is it to use the BIA device in home settings?	CHN feedback
		Burden	Does the measurement require a reasonable amount of time, or does it burden the clinicians, parents, or children?	CHN feedback
		Logistical Challenges	Can the BIA device be easily transported?	CHN feedback
		Data Collection Procedures	Is the protocol for data collection procedures feasible and appropriate?	CHN feedback
Adaptation	Referring to how well the BIA method can be adjusted or modified to fit the needs of assessing infant BIA at home. It considers whether any changes or accommodations are necessary to make the method suitable for this context.	Integration in Home Settings	How easy is it to adapt the BIA method in home settings for 2-year-old children?	CHN feedback
		Integration into Healthcare Services	Can the BIA method be easily integrated with the existing healthcare services?	CHN feedback
Resources Needed	This refers to the materials, equipment, time, and personnel required to successfully perform BIA on children at home. It includes evaluating the availability and accessibility of these resources.	Training Requirements	Do the CHNs have the necessary expertise and skills to conduct the BIA measurement?	CHN feedback
		Equipment Availability	Is equipment available when needed?	CHN feedback
Acceptability	Involves determining whether the use of BIA in the home is acceptable to those involved, including parents and children. It considers factors like comfort, willingness to participate, and any concerns about the method.	Parents Children	Are the procedures of BIA measurements acceptable to parents and children?	CHN feedback Parent feedback

2.3. Statistical analysis

All descriptive data are presented as mean ± standard deviation (SD) for continuous variables, while categorical variables are presented using frequencies accompanied by percentages (%). The completion rate was calculated as the number of completed measures divided by the total number of participating children. BMI and weight-for-length z-scores were calculated using the World Health Organization (WHO) growth standards. All analyses were performed in R version 4.3.3 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1. Participant characteristics

In the feasibility study, 72 children (66 % boys) were invited to participate, but two parents withdrew consent before the planned visit. The mean age was 24.21 ± 1.21 months, with boys being taller and heavier than girls (Table 2).

Table 2
Characteristics of young children($N = 72$) assessed for home-based bioelectrical impedance analysis (BIA) in Denmark (January 2022–March 2025).

	Mean (SD[1]) population characteristics		
	Boys ($n = 46$)	Girls ($n = 26$)	All (n = 72)
Age (months)	24.0 (1.1)	24.5 (1.4)	24.2 (1.2)
Length (cm^2)	89.0 (3.7)	87.6 (3.8)	88.5 (3.8)
Weight (kg^3)	13.3 (1.5)	12.4 (1.2)	13.0 (1.4)
BMI[4] (kg/m^2)	16.8 (1.3)	16.2 (1.2)	16.6 (1.3)
$BMI^4_{z\text{-score}}$	0.6 (1.0)	0.4 (0.9)	0.5 (1.0)
$Weight\text{-}for\text{-}length_{z\text{-score}}$	0.6 (1.0)	0.4 (0.8)	0.5 (0.9)

[1]SD, Standard deviation.
[2]cm, centimeter.
[3]kg, kilograms.
[4]BMI, Body Mass Index.

3.2. Feasibility evaluation

3.2.1. Suitability

Among attempted BIA measurements, the completion rate was 71 % ($n = 50$ / 70 measurements). Barriers included child cooperation ($n = 11$ / 20 (55 %) of not completed measurements), such as fear, scepticism, and resistance to electrode placement. Other barriers were the limited availability of two devices shared among CHNs and technical difficulties ($n = 6$ / 20 (30 %) of not completed measurements), such as device failing to display results, inconsistent skin impedance readings, and calibration problems. The CHNs reported that these problems were difficult to handle due to the infrequent use of the device compared to other routine tasks.

3.2.2. Practicality, adaptation, and resources needed

All CHNs found the ImpediMed SFB7 device easy to use and the measurement protocol appropriate and easy to follow. Although the alligator clips and wires were heavy and bulky for young children's hands and feet, preparing them in advance eased the process. No CHNs felt additional training was needed, as the procedures were easy to follow, though they suggested further education to interpret and explain BIA results to parents.

Although the actual impedance measurement takes less than a second, sessions typically lasted five minutes, occasionally, up to ten minutes, depending on child cooperation. While this was not considered a significant time commitment, it caused logistical problems in the CHNs' time schedule. Nevertheless, the CHNs considered it feasible to integrate BIA measurements into their daily work routine.

Most completed measurements ($n = 32$, 70 %) were rated as easy or very easy (Fig. 3). Preparing the child and attaching electrodes was the most challenging step. Helpful strategies included allowing the child to sit on a parent's lap, using cartoon stickers for distraction, and providing clear explanations. CHNs considered measurements at home as more comfortable and less stressful for parents and children than in the hospital, though, the availability of more staff in hospitals could facilitate

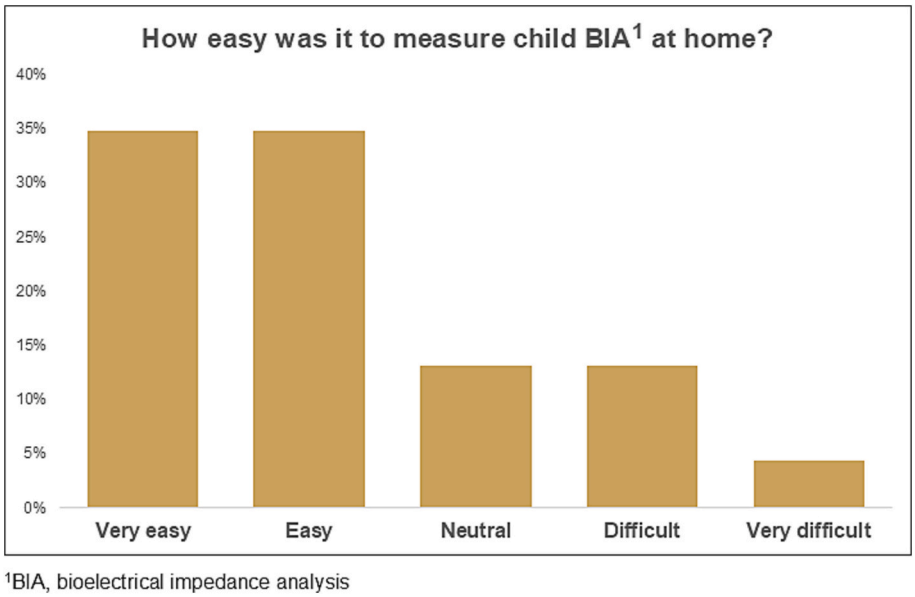


Fig. 3. Ease of use of the bioelectrical impedance analysis (BIA) device during home visits in young children as reported by community health nurses (CHNs) in Denmark (January 2022–March 2025). Data were missing from four participants.

measurements in situations where the child is not cooperating.

3.2.3. Acceptability

Parents raised no significant concerns during or after the measurements. After each measurement, parents were asked to provide feedback on their experience and their perception of the child's comfort. Overall, 96 % ($n = 27 / 28$) reported a positive experience, describing the process as straightforward and minimally intrusive (Fig. 4). Parents reported that 79 % ($n = 22 / 28$) of children found the measurement comfortable and acceptable (Fig. 4).

4. Discussion

This study is the first to develop and test a standardised, developmentally appropriate protocol for home-based BIA measurement in young children. It addresses a methodological gap in applying body composition assessment tools in early childhood and home-based settings. Feasibility was evaluated in a community-based sample of 70 two-year-old children, of whom 71 % completed the measurements. The procedures were easy to perform, quick, and suitable, completed in most children with high acceptability among parents, children, and CHNs.

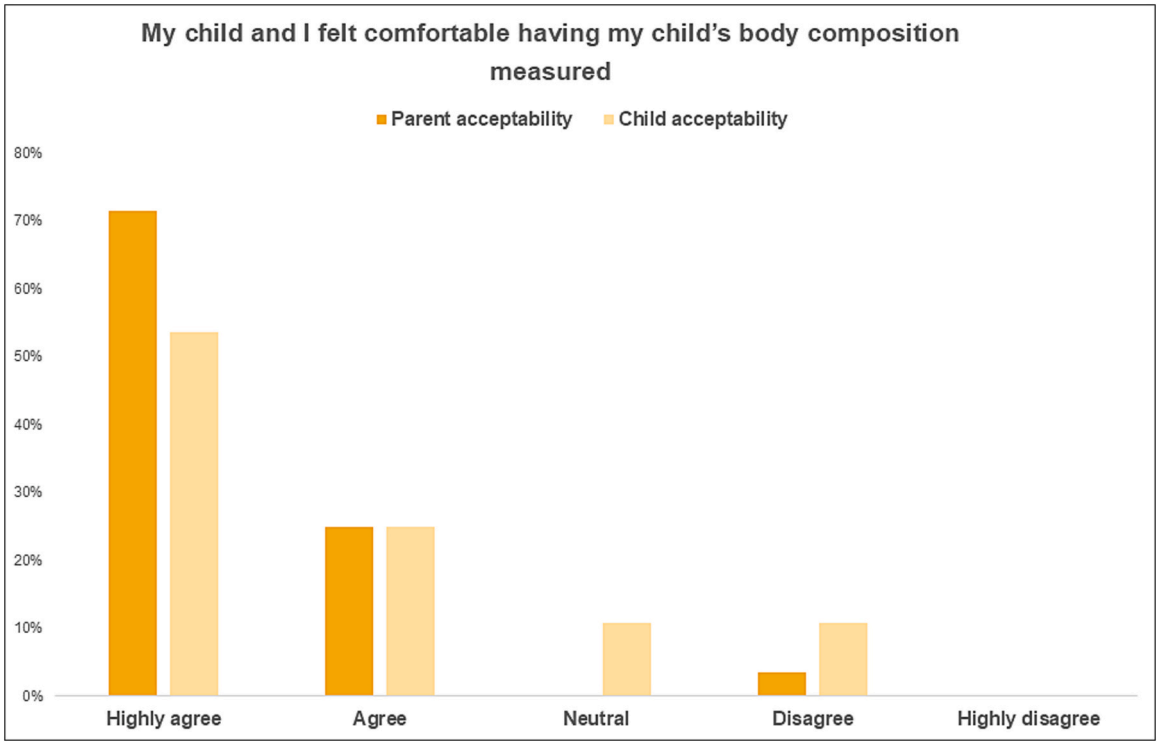


Fig. 4. Parent and child acceptability assessed after each bioelectrical impedance analysis (BIA) measurement as reported by the parents in Denmark (January 2022–March 2025). Data were missing from 22 participants because the questionnaire on acceptability was implemented halfway through the study.

These findings indicate that BIA measurements can be successfully conducted when tailored to the child's developmental stage.

Growing literature advocates for consensus BIA measurement guidelines to reduce variability and inconsistency, with significant implications for clinical practice and research (Ward, 2018; Orsso et al., 2022; Brantlov et al., 2017a; Lyons-Reid et al., 2020; Brantlov et al., 2017b). Given that at least 30 factors may affect BIA measurements (Brantlov et al., 2017a), developing and implementing standardised guidelines is crucial for enhancing accuracy and utility. Orsso et al. recommend that paediatric studies follow either manufacturer protocols or previous study recommendations (Brantlov et al., 2017a; Lyons-Reid et al., 2020) until a standard paediatric protocol is established (Orsso et al., 2022). Previous studies have used varied methods, with some relying on protocols designed for older children and adults, which may not be directly applicable to younger children (Brantlov et al., 2019; Olsen et al., 2012). Our pilot study showed that ImpediMed's protocol is not feasible in young children, with cooperation being the main barrier. Children aged one and four years must be met developmentally appropriately to feel physically and mentally secure in unknown situations (Illingworth, 2021). Taken these challenges into consideration, using an age-appropriate protocol resulted in a 71 % completion rate ($n = 50$ out of 70 measurements), with 32 of the 50 (70 %) completed measurements rated as easy or very easy by the CHNs. Measurement difficulties in young children are not unique to BIA; measuring electroencephalography (EEG) show similar challenges with attrition rates up to 45–50 %, mainly due to child non-compliance and motion-related signal contamination (Noreika et al., 2020; Bell and Cuevas, 2012). Our results suggest that balancing parental involvement with children's developmental needs can improve cooperation, which may be applicable to different settings and various measurement tools. Training motivated data collection staff in both the BIA method and in meeting the needs of the child may further enhance the feasibility. Future recommendations include providing parents with illustrative material, such as a video or a picture book, before the visit to familiarise the child with the procedures.

One of the most important recommendations for BIA measurement is to place the electrodes accurately in anatomically defined locations, which is why we used dual ECG-style electrodes. Methodological considerations and testing of both critical and non-critical factors were carried out to ensure that the assessment was as feasible and applicable as possible (Brantlov et al., 2017a; Lyons-Reid et al., 2020). However, one critical factor - cleansing the skin with alcohol - was not feasible in young children. While adult studies have shown that cleansing without alcohol may lead to minor measurement errors (Gonzalez-Correa and Caicedo-Eraso, 2013), the strong smell and cold sensation of alcohol hindered child cooperation. Although adult guidelines recommend supine positioning, studies have shown reliable measurements regardless of body position (Lyons-Reid et al., 2021b; Koelmeyer et al., 2020). Stand-on devices may offer a more feasible option for future assessments (Koelmeyer et al., 2020), but current models are designed for adults and unsuitable for young children; in a previous study, researchers modified a stand-on device for paediatric use (Lopez-Gonzalez et al., 2022). Although the SFB7 device was designed for research, CHNs in the present study found the measurement protocol easy to follow and the device appropriate for use. Still, guidelines for interpretation of measurement results are needed for non-specialists to support broader clinical use.

Home monitoring and self-management interventions have positive impacts on several health conditions (Pais-Cunha et al., 2024; Crawford et al., 2023), and home self-measurement using BIA has proven feasible and acceptable among adults (Koelmeyer et al., 2021). Integrating home-based BIA into paediatric research and care eliminates logistical barriers and provides a more comfortable environment for children, potentially enabling more accurate and less stressful measurements. In this study, 96 % of parents ($n = 27$) found the measurement procedures comfortable and acceptable, and 79 % ($n = 22$) thought that their child felt the same, underlining the potential of home-based measurements. However, logistical aspects like time burden for health professionals and practical at-home implementation must be addressed. The CHNs reported moderate burden coordinating two devices with existing workloads but noted that BIA could be integrated into existing healthcare services if barriers such as child cooperation, access to equipment, and technical issues are addressed. Overall, the findings of this study provide practical insights regarding the practicability, required adaptations, and resource needs for integrating home-based BIA into paediatric care.

Although this study demonstrates the feasibility of measuring BIA in young children, several limitations must be acknowledged. This study focused on feasibility and was not designed as a validation study; therefore, the accuracy of BIA measurement in children was not assessed. Hence, BIA measures were not included in the present study. While BIA is not considered a reference method for body composition data, it is regarded as a suitable tool for field and clinical use, particularly for monitoring changes over time and for group-level comparisons, rather than for absolute classification (Gallagher et al., 2020; Ward et al., 2013). Normative data from accepted reference methods (e.g., four-compartment models and DXA) exist, but their translation to BIA should be approached with caution (Lyons-Reid et al., 2024; International Atomic Energy Agency (IAEA), 2013; Hills et al., 2024; Butte et al., 2000; Wells, 2014). This underscores the need for future studies to establish reference ranges in young children and to validate BIA in this population against gold standard technique such as DXA (Ward, 2019). The small sample size may limit the generalisability of the findings; nonetheless, this size is considered acceptable for feasibility studies (Orsmond and Cohn, 2015). However, only five CHNs were involved in this study, and two of them were involved in the protocol development. BIA measurement requires training, and operator variability, which was not examined in this study, may impact BIA measurement accuracy. Since the study was home-based, findings may not apply to clinical or other settings. Further research is needed to refine measurement techniques and validate findings in larger, more diverse populations and settings.

In clinical and research settings, it is valuable to have a simple, inexpensive method of measuring body composition that is practical with respect to time, comfort, and repeatability. BIA meets these requirements, and this study proposes a new, developmentally adapted, standardised protocol for BIA measurement in young children that, although developed in Danish setting, holds relevance for global implementation and helps fill a critical methodological gap. While some logistical and technical challenges remain, the overall feasibility and acceptance support integrating BIA into early childhood obesity assessment in both clinical care and research (Wells and Fewtrell, 2008).

CRediT authorship contribution statement

Clara Barfod Parellada: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis. **Leigh C. Ward:** Writing – review & editing, Formal analysis, Conceptualization. **Anne Mette Skovgaard:** Writing – review & editing, Supervision, Funding acquisition, Formal analysis, Conceptualization. **Grete Katrine Teilmann:** Writing – review & editing, Supervision, Formal analysis. **Bo Mølholm Hansen:** Writing – review & editing, Supervision, Methodology, Formal analysis. **Steven Brantlov:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization.

Funding

The study was supported by a grant from the Independent Research Fund Denmark (Grant reference number 9130-00071B) and the Novo Nordisk Foundation (Grant reference number 20SH0063466). The funders have no influence on study methods, analysis, interpretation, or publication of results.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Author Leigh C Ward provides consultancy services to ImpediMed Ltd., which was not involved in preparing the manuscript. The other authors have no conflicts of interest to declare regarding this work.

Acknowledgments

We are grateful to all participating parents and children, and to Maiken Hauge Stig and the community health nurses, Mette Bagge Møller, Julie Rathsach, Majbritt Vonsild, Camilla Dahl Kristensen, and Mette Karlsen, who were involved in the data collection.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2025.103270.

Data availability

The datasets (and materials) generated and analysed during the current study are available from the corresponding author upon reasonable request.

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