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Remote Early Follow-Up: Home Videos Enabled Reliable General Movement Assessment With Only Weak Association With the Ages and Stages Questionnaire

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ABSTRACT

Aim: This observational follow-up study of very preterm infants evaluated home videos for General Movements Assessments (GMA), the remote Ages and Stages Questionnaire (ASQ) and associations between the two tools at 3–4 months of corrected age.

Methods: We enrolled 232 infants born before 32 weeks of gestation from eight neonatal units in Eastern Denmark during 2021–2023. Parents received In-Motion video instructions, based on the General Movements Trust guidelines and submitted home recordings via the Baby Moves app. They completed the ASQ electronically. Experienced GMA observers independently assessed the videos.

Results: Parents submitted videos for 184 infants (79%) and all were suitable for evaluation. They also completed the ASQ for 199 infants (86%). Interobserver agreement for typical GMA versus atypical classifications was excellent (Gwet's AC1 = 0.97). Eight infants (4%) showed atypical GMA, indicating a high risk of cerebral palsy. ASQ data were available for seven of these infants. GMA and ASQ classifications showed a weak association ($p = 0.03$, Phi = 0.19). Four of the seven children with atypical GMA had low total ASQ scores, whereas 31/35 children with low total ASQ scores had typical GMA.

Conclusion: Home videos enabled reliable early GMA assessments for cerebral palsy risks. ASQ and GMA classifications showed weak associations.

1 | Introduction

Preterm birth remains a leading contributor to worldwide neonatal mortality and long-term morbidity [1]. Despite significant advances in neonatal care and improved survival rates, infants born preterm, particularly before 32 weeks of gestation, continue to face a substantially increased risk of neurodevelopmental disorders [2]. Cerebral palsy (CP) is a major concern, which has been reported to affect approximately 5% of infants born before 32 weeks of gestation. This was more than a 30-fold increased risk when the data were compared with term-born peers [3].

Follow-up programmes are a critical component of neonatal care, but their content varies widely across healthcare systems [4]. Early detection and timely intervention for CP are essential and follow-up programmes should aim to identify high-risk infants, while balancing resource use and minimising the burden

Abbreviations: ASQ, ages and stages questionnaire; CP, cerebral palsy; GMA, general movements assessment.

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Key Points

- Follow-up assessments at 3–4 months corrected age of preterm infants born before 32 weeks of gestation should identify those at high risk of cerebral palsy.
- Parent-recorded home videos enabled reliable general movements assessments (GMA) in 184 infants, while parents also completed the Ages and Stages Questionnaire (ASQ).
- Home videos may facilitate the use of GMA in early follow-up, while GMA and ASQ were only weakly associated at this age.

on families [5]. That is why eHealth solutions have been explored, to improve accessibility and efficiency in follow-up care [6–8].

Identifying infants with a high risk of CP at an early stage relies on specialised assessment tools. These include the general movements assessment (GMA), which has been reported to be highly accurate [5, 9]. Studies have reported that it showed particular predictive accuracy during the fidgety movement period around 3 months of corrected age, when the absence of fidgety movements strongly indicated a high risk of CP [5, 10–13]. Despite its prognostic value, the use of the GMA in follow-up programmes has varied. This has probably been due to its reliance on trained assessors, the need for ongoing calibration and the practical challenges posed by clinical assessments [14–16]. Remote GMA is now possible due to the development of smart phone applications, such as the Baby Moves app, together with enhanced parental guidance provided by the In-Motion video instructions [7].

Smartphones have made it possible to record a child's movements at home, and this could provide a feasible and promising approach for expanding the use of the GMA [6–8, 14].

Developmental surveillance is also part of follow up, including assessment of developmental milestones [17]. The Ages and Stages Questionnaire (ASQ) is a widely used milestone-based screening tool [18, 19]. As a parent-reported instrument, it is user-friendly, cost-effective and can be completed at home, which offers flexibility for families. The ASQ appeared to be useful for children at 18–24 months [20] and it may help to guide further assessments. However, its value for follow ups at earlier ages remains uncertain [21, 22].

The primary aim of this study was to evaluate the clinical usability of home-video recordings for GMA for follow-up assessment of infants born before 32 weeks of gestation. In addition, we explored ASQ scores at age 3–4 months and their associations with GMA classifications.

2 | Methods

2.1 | Study Design and Setting

This observational study was conducted in Eastern Denmark, a region with approximately 2.8 million inhabitants and about 28 000 annual deliveries. Infants born before 28 weeks of gestation are initially treated at the only centralised Level 3 neonatal intensive care unit at the Rigshospitalet in Copenhagen. After that, neonatal care is provided by eight neonatal units that use the same unified electronic health record system.

In Denmark, all infants born before 32 weeks of gestation are routinely followed up, due to their increased risk of adverse neurodevelopmental impairments. Follow-up care is primarily decentralised, with responsibility delegated to the local neonatal unit. There are no national guidelines regarding follow-up procedures during the first year of life.

This study added two home-based eHealth tools to the local follow-up practices. Parents of the participating infants submitted video recordings for GMA evaluation and completed the ASQ electronically. The GMA outcomes were recorded in the infants' medical records. If the movements were classified as typical, the parents were informed directly by the principal investigator (AB) and the result was documented accordingly. If the infant displayed atypical movements, which suggested a high risk for CP, their local paediatrician contacted the family and coordinated any further follow-up care.

2.2 | Participants

The study population was preterm infants born before 32 weeks of gestation at one of the eight Danish neonatal units. They were recruited from 1 August 2021 to 30 April 2023. Local clinical staff informed the families about the study before the infants were discharged. At least one parent had to speak Danish or English. Parents who were interested were subsequently telephoned by the primary investigator and provided with detailed information about the study procedures, including the home video recordings and the ASQ.

2.3 | Data Sources and Assessment Tools

2.3.1 | Background and Clinical Course

The cohort was described using infant demographic and perinatal medical data that were extracted from medical records. These were entered into the Research Electronic Data Capture (REDCap) database (Vanderbilt University, Tennessee, USA) for secure storage and management.

The demographic data included sex, gestational age, birthweight, and classification as small for gestational age [23]. Perinatal medical data included clinical information during the neonatal admission (Table 1). In addition, attendance at the scheduled routine local follow-ups was recorded for each infant.

2.3.2 | ASQ

The ASQ is a developmental screening tool that is designed to identify potential delays in infants and young children aged 1 month to 5 years and 6 months. It is a norm-referenced instrument that is completed by parents and captures their perceptions of their child's development across five key domains. These are communication,

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TABLE 1 | Characteristics of 232 infants in the study cohort.

Variable	Value
Gestational age, median in weeks/days (IQR 25%–75%)	29 + 6 (27 + 2 to 31 + 1)
Gestational age < 28 + 0 weeks/days, *n* (%)	60 (26)
Gestational age: 28 + 0–31 + 6 weeks/days, *n* (%)	172 (74)
Birthweight, median in grammes (IQR 25%–75%)	1263 (1016 to 1517)
Small for gestational age[a], *n* (%)	57 (25)
Male sex, *n* (%)	126 (54)
Surfactant treatment, *n* (%)	117 (50)
Mechanical ventilation during admission, *n* (%)	72 (31)
Bronchopulmonary dysplasia[b], *n* (%)	48 (21)
Necrotising enterocolitis operata, *n* (%)	4 (2)
Retinopathy of prematurity treatment, *n* (%)	11 (5)
Intraventricular haemorrhage Grade 3/4 or cPVL	7 (3)

Abbreviations: cPVL, cystic periventricular leukomalacia; IQR, interquartile range.
[a]Small for gestational age calculated using Marsal et al. [23].
[b]Need for respiratory support at 36 weeks of postmenstrual age.

gross motor, fine motor, problem-solving and personal-social skills. Each domain comprises six items that reflect age-appropriate developmental milestones. Responses are scored as 10 points for yes, five points for sometimes, and zero points for not yet. The domain-specific scores range from 0 to 60 and the total scores range from 0 to 300. The parents completed all five domains, and a total score of below 183 indicated developmental concerns, based on normative thresholds in the ASQ manual [18].

2.3.3 | Home Videos and the GMA

Home video recordings were collected using the Baby Moves application (Murdoch Children's Research Institute, Victoria, Australia), a smartphone application developed to remotely assess infant motor behaviour [24]. The app enables parents to record and securely upload videos of their infant's spontaneous movements. To ensure quality and standardisation, parents were provided with an In-Motion instructional video (Norwegian University of Science and Technology, Trondheim, Norway) [7]. This was in Danish and based on General Movements Trust guidelines. English language support was available from the primary investigator, if required. Parents were notified by the Baby Moves app to record their infant during two separate time windows: from 12 + 1 to 13 + 6 weeks/days and from 14 + 1 to 17 + 6 weeks/days of corrected age. The primary investigator contacted the family before the first time-window and again if no video recording was uploaded at 16 weeks of corrected age.

All the videos were initially assessed as scorable or not scorable, based on standard GMA criteria. This included spontaneous motor activity, supine position, appropriate behavioural state, minimal clothing with just a bodysuit or diaper and absence of distractions. The smartphone camera needed to be correctly placed, with adequate lighting and the infants' full body needed to be visible. The GMA scorable videos were independently reviewed for fidgety movements by two certified GMA observers. AB worked in one of the neonatal departments and was aware of the infants' medical histories, while LA was blinded to these. Disagreements were resolved through consultation with a third certified observer (TF), until a majority consensus on the classification was reached. GMA was typical when fidgety movements were present and included continuous, intermittent or sporadic fidgety movements, between 6 and 8 weeks of corrected age or during the fifth month. GMA was atypical when fidgety movements were absent or abnormal, due to exaggerated amplitude and speed. Videos with fidgety movements were prioritised if multiple recordings with different classifications were submitted [25].

2.4 | Statistical Analysis

Descriptive statistics are presented as frequencies and percentages for nominal variables, medians with interquartile ranges for ordinal variables, and means with standard deviations for continuous variables.

Interobserver reliability for classifying fidgety movements as typical or atypical was assessed using Gwet's agreement coefficient 1, which provides more robust estimates than Cohen's kappa coefficient in the presence of prevalence imbalance [26]. However, Cohen's kappa was calculated to assess agreement for comparison and interpretability [27].

Analyses that examined associations between the GMA and ASQ were conducted on complete cases. The ASQ is a screening tool for developmental delay and scores often cluster near the upper limit in above-average infants, resulting in skewed distributions. Therefore, the associations between ASQ total scores and GMA classification were assessed using the Mann–Whitney U test. This compared median ASQ scores between infants with typical and atypical GMA results. In addition, Fisher's exact test was used to analyse associations between low and normal ASQ scores and the GMA classifications. The Phi coefficient was used to measure the strength of these associations.

All the statistical analyses were performed using SPSS Statistics version 29.0 (IBM Corp, New York, United States).

2.5 | Ethics

The study was approved by the Danish Data Protection Agency (P-2021-125). It was conducted in accordance with ethical guidelines for research involving vulnerable populations produced by the World Health Organisation and the Council for International

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Organisations of Medical Sciences. No additional ethical approval was required under Danish national regulations, because the study was observational and posed minimal risk. Written, informed consent was obtained from the parents of the participating infants.

3 | Results

3.1 | Description of the Cohort

One family withdrew consent and 232 preterm infants (54% male) were included in the study. There were 169 singletons and 63 infants from multiple births. The median gestational age was 29 + 6 weeks/days and the median birth weight was 1263 g. Just over a quarter (26%) were born at less than 28 weeks of gestation, while the other 74% were born from 28 + 0 to 31 + 6 weeks/days of gestation. Detailed demographic characteristics and data on respiratory support and neonatal morbidities are presented in Table 1.

3.2 | GMA

The parents of 184 (79%) of the 232 infants eligible for follow up at 3–4 months submitted at least one video for GMA (Figure 1). Of these, 90% successfully uploaded recordings via the Baby Moves app, while the other 10% used alternative methods due to app-related technical difficulties.

The 48 families (21%) who did not return video recordings were asked for their reasons: 14 (6%) cited technical issues and 34 (15%) did not respond. We found that 41 of the 48 infants attended a follow-up clinic between 3 and 5 months of corrected age, while two missed outpatient follow ups entirely.

Videos from 184 infants were assessed, and all infants could be classified according to their GMA fidgety movements, and none of the cases showed different overall classifications when more than one video was available. Interobserver agreement was 97%, and inter-rater reliability was high, with a Gwet's AC1 coefficient of 0.97 (95% confidence interval 0.94–1.00) and a Cohen's kappa of 0.69 (95% confidence interval 0.44–0.95). Overall, 96% of the infants had typical fidgety movements and 4% had atypical movements. The parents of seven of the eight infants with atypical GMA findings completed the ASQ. The eighth family did not return the questionnaire and were excluded from analyses examining associations between the GMA and ASQ findings (Table 2).

3.3 | ASQ

Of the 232 families eligible for follow ups at 3–4 months, 199 returned (86%) the ASQ and these were all scorable (Figure 1). No specific reasons were reported for the 33 families who did

TABLE 2 | Relation between classifications by GMA and ASQ in the 174 infants with results on both tests.

	Typical GMA	Atypical GMA	Total
ASQ normal score	136	3	139
ASQ low score	31	4	35
Total	167	7	174

Abbreviations: ASQ, ages and stages questionnaire; GMA, general movements assessment.

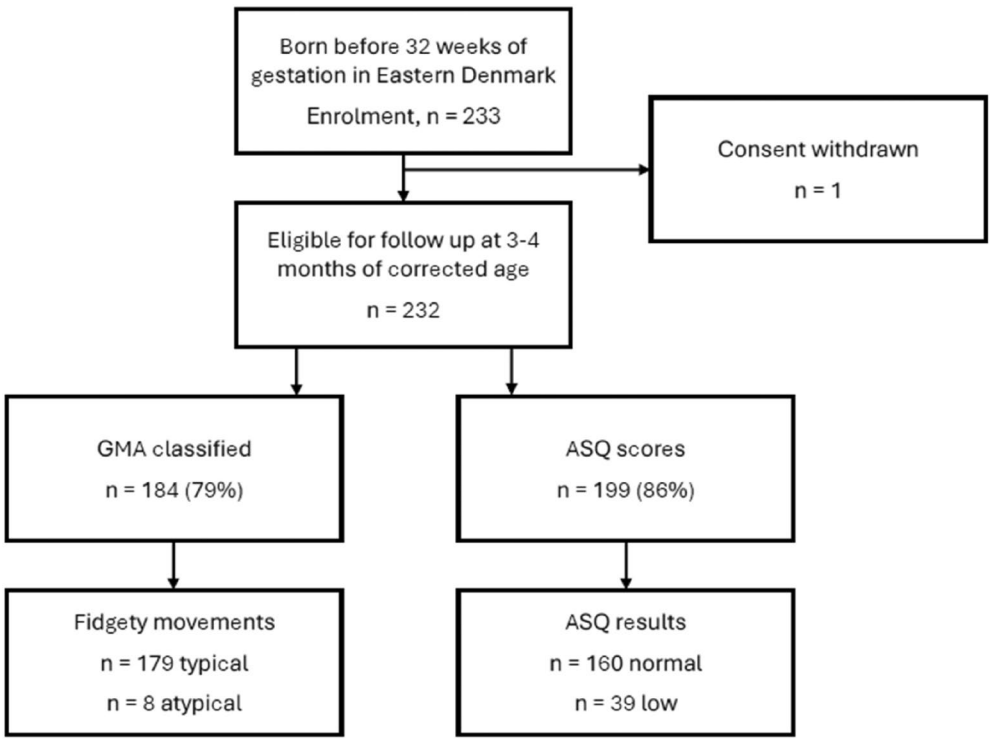


FIGURE 1 | Participation flowchart. Parallel flowchart illustrating participation in the GMA and ASQ by the 232 infants and their outcomes. The diagram highlights the classification of fidgety movements and developmental screening results based on ASQ.

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not complete the electronic questionnaire. However, 29 of the 33 infants attended a follow-up clinic between 3 and 5 months of corrected age, but two did not attend any outpatient follow ups at all. Overall, 160 infants (80%) had scores within the normal range, while 39 infants (20%) had low scores.

3.4 | Associations Between the GMA and ASQ

The associations between the ASQ scores and GMA classifications are presented in Figure 2. The median ASQ score among infants with typical GMA was 220, compared to 140 for those with atypical GMA ($p = 0.07$).

Fisher's exact test showed a statistically significant association between GMA and ASQ classifications ($p = 0.03$). However, the strength of the association was weak ($\varphi = 0.19$). Although atypical GMA findings were more frequent among infants with low ASQ scores, 31 of the 35 infants with low ASQ scores had typical GMA findings.

4 | Discussion

This study examined the clinical use of video recordings for GMA, filmed by parents at home, during the early follow up of preterm infants born before 32 weeks of gestation. Most families submitted home recordings and nearly all the videos were suitable for assessment, with high interobserver reliability. GMA identified eight children (4%) with atypical findings, which indicated a high risk of cerebral palsy. The parents of seven of these children completed the ASQ and were included in the analyses that examined associations between the two assessments. The ASQ was completed by 86% of all the families, and low scores were observed in 20% of their children. Although a weak association was found between the ASQ classification and GMA findings, the results suggested that low questionnaire scores at 3–4 months should not be interpreted as indicators of increased CP risk.

Previous studies have explored using home videos, supported by eHealth, for GMA in diverse settings. For example, a study from Nepal reported a video submission rate of only 52%, which probably reflected the practical challenges of implementing such technology in low-resource environments [6]. In contrast, studies from high-income countries have demonstrated participation rates similar to ours. A large Australian population-based study that used the Baby Moves App reported a 76% submission rate [28], while a multicentre study that investigated the Norwegian In-Motion app achieved 80% [7]. Notably, a Norwegian follow-up study that used the In-Motion instructions reported that 97% of families successfully submitted a home video suitable for GMA [14]. The high interrater reliability in our study was also found in another population-based study of home videos that used the Baby Moves app [29].

Our results further support the clinical use of handheld home videos for GMA and suggest that eHealth approaches are both feasible and acceptable during follow ups. Our findings also highlight that a significant proportion of families may not complete the home video submission process. Approximately 20% of our families did not submit a home video, despite our structured research settings. However, nearly all the families attended their scheduled follow-up appointments at their local clinics.

We also examined the ASQ scores and their associations with GMA classifications and this showed that atypical GMA was predictive for CP. ASQ at 6–8 months has been reported to predict severe impairment in infants with hypoxic–ischemic encephalopathy, but early developmental assessment of neurotypical infants correlated poorly with later outcomes [30, 31].

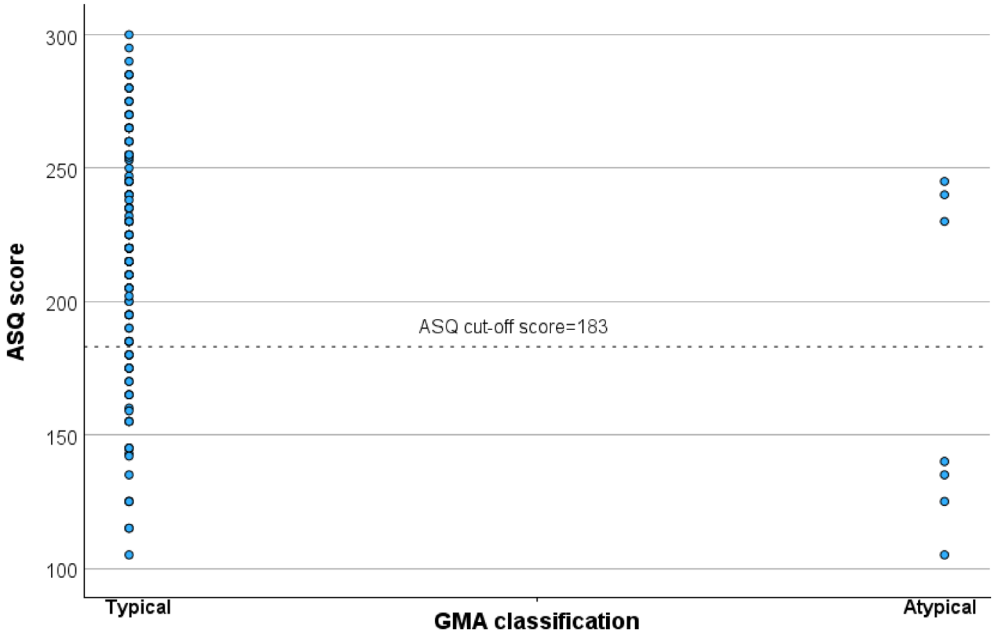


FIGURE 2 | ASQ scores by GMA classification. Scatterplot of ASQ scores by GMA classification in atypical and typical cases. The dashed horizontal line indicates the ASQ cut-off score of 183, which distinguished normal (≥ 183) from low (< 183) ASQ scores.

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However, early developmental scores at age 5 months have been associated with later outcomes in preterm children later diagnosed with neurodevelopmental impairments [31]. This may explain the associations we observed between the ASQ classifications and GMA in our cohort. The ASQ is a developmental surveillance tool and should not replace comprehensive clinical assessments in early follow ups. In our cohort, few infants with normal scores were classified as high risk for CP by the GMA findings, while most infants with low ASQ scores had typical GMA. These findings emphasise the importance of using targeted assessments to identify infants with high risks for cerebral palsy at this age. Another consideration for future research is whether the Motor Optimality Score–Revised may demonstrate stronger associations with developmental screening tools, such as the ASQ. Unlike the GMA classification, which is categorical, that score provides a continuous measure of motor repertoire and movement quality. This approach may capture more subtle variations in early motor development and potentially improve alignment with broader developmental outcomes.

Given the growing interest in integrating GMA into routine follow-up programmes, eHealth solutions that enable parents to submit home videos offer clear advantages, including improved accessibility and convenience. This could expand the use of GMA in follow-up programmes. Home video recordings may not be feasible for all families, due to technological or contextual challenges. However, our study showed that eHealth approaches played an important role in the early follow up of infants born before 32 weeks of gestation. To ensure equitable follow up for all infants and their families, they should be regarded as a complement to, not a substitute for, face-to-face clinical assessments. Smartphone videos for GMA evaluations may also be recorded in hospital settings if home videos are not provided. Further research is needed to optimise these strategies and strengthen early follow-up programmes.

4.1 | Strengths and Limitations

The main strength of this study was that we focused on a general population of preterm infants born before 32 weeks of gestation. We did not restrict them to those with additional detectable risk factors for cerebral palsy at the time of the study. This enhanced the generalisability of our findings to typical populations included in follow-up programmes. A key limitation was the relatively small number of infants classified with atypical GMA. While this was consistent with the expected incidence of cerebral palsy in this group, many of the results had wide confidence intervals. Interrater reliability was high, despite relying on home-based handheld smartphone video recordings by parents, rather than standardised recordings during clinic assessments. However, using handheld recordings in uncontrolled home environments may introduce variations when compared to traditional clinical GMA procedures. An ongoing 2-year follow up of this cohort is being carried out to assess the predictive value of GMA and ASQ from the present study.

5 | Conclusion

Home videos recorded by parents enabled clinical experts to carry out reliable GMA assessments for early cerebral palsy risks. Although a weak association was found between the ASQ classifications and GMA findings, the results suggested that low ASQ scores at 3–4 months should not be interpreted as indicators of high CP risk. We concluded that eHealth approaches may play an important role in the early follow up of infants born before 32 weeks of gestation. However, face-to-face clinical assessments are still essential to ensure equitable and comprehensive follow ups for all infants and families.

Author Contributions

Annemette Brown: conceptualization, investigation, writing – original draft, methodology, validation, visualization, writing – review and editing, formal analysis, project administration, data curation, resources. **Bo Mølholm Hansen:** conceptualization, funding acquisition, methodology, validation, visualization, writing – review and editing, supervision, writing – original draft. **Katarina Lauruschkus:** conceptualization, writing – review and editing, supervision, methodology. **Lars Adde:** methodology, validation, writing – review and editing, formal analysis, supervision, conceptualization. **Åsa B. Tornberg:** conceptualization, writing – original draft, methodology, validation, writing – review and editing, formal analysis, supervision.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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