Brief Report

Feasibility and reliability to assess the motor development of infants exposed to gestational COVID-19 using the Alberta Infant Motor Scale remotely

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Abstract: The virus infection severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) during pregnancy is a risk factor for developmental problems. Our objectives were to explore feasibility measures and verify the reliability of synchronously employing the Alberta Infant Motor Scale (AIMS) remotely in infants with prenatal exposure to SARS-CoV-2. Additionally, we explored the motor performance of these infants relative to an unexposed normative sample. An exploratory cross-sectional study was carried out and included 20 infants (10.65±4.99 months) whose mothers tested positive for coronavirus disease 2019 (COVID-19) during pregnancy. Infants were assessed with the AIMS remotely and synchronously via video call by a physical therapist. The calls were recorded. Three independent observers scored the recordings. Parents and assessors answered questions regarding barriers to and facilities for the assessments. A higher proportion of parents (90%) found it easy to understand and replicate the commands provided by the therapist during the assessment (P<0.001). The assessors reported not encountering difficulty in most assessments. Interobserver reliability was good in the standing posture [95% confidence interval (CI): 0.734–0.942, P<0.001] and excellent (95% CI: 0.970–0.996, P<0.001) in prone, supine, and sitting. Intra-rater reliability was excellent (95% CI's: 0.876–1.000, P's<0.001) in all postures. There were no differences between the motor performance of exposed infants compared to the unexposed normative sample. It was feasible to assess the motor performance of infants exposed to SARS-CoV-2 via video call with good to excellent inter- and intra-rater reliabilities, making it an important approach when social distancing is needed.

Keywords: Telemonitoring; coronavirus; motor skills; child development

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Introduction

The coronavirus disease 2019 (COVID-19) pandemic, caused by the novel coronavirus, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has had invaluable impacts worldwide (1). While it primarily affects the pulmonary system, the disease is a multisystemic infection, and the involvement of the peripheral and central nervous systems has been increasingly recognized (2-4).

Studies have shown that the potential risk of neurodevelopmental impairments over the first 12 months after birth may be associated with prenatal exposure to SARS-CoV-2 (5-7). Nonetheless, as of now, there have yet to be studies that have specifically assessed motor skills within this population.

One of the primary challenges in monitoring the motor behavior of infants exposed to SARS-CoV-2 during the COVID-19 pandemic was the need to maintain social distancing. Telemedicine became a viable solution, allowing individualized remote assessments of infants (8,9). Specifically for assessing motor skills, the Alberta Infant Motor Scale (AIMS), a widely validated scale used to assess the gross motor performance of infants in the first 18 months of life (10), has been applied via telemedicine (11-15). Although the inter-rater reliability of telemonitoring motor development using the AIMS has been studied by Lima *et al.* (13), they assessed infants asynchronously. Therefore, the practicality and reliability of using the AIMS synchronously still need to be determined, and potential facilities and barriers may be present in real time. Furthermore, no studies employing the AIMS to assess the motor performance of infants exposed to SARS-CoV-2 infection have been found. Exploring this issue is important to understand the motor characteristics of this population, particularly relative to a local normative sample that was not exposed to the COVID-19 pandemic environment.

In this study, we verified the use of AIMS via video call for assessing the motor performance of infants with prenatal exposure to COVID-19. Specifically, we aimed to explore feasibility measures and verify the reliability of synchronously employing the AIMS remotely. In addition, we explored the results of their motor performance relative to those obtained from a normative sample before the pandemic. Finally, we provided detailed information on maternal immunization and perinatal complications for each infant assessed. The findings help determine the practicality and reliability of the synchronous use of AIMS for remote assessments of infants and contribute to the knowledge of the clinical and motor characteristics of infants exposed to gestational COVID-19.

Methods

Study design and participants

This is an exploratory cross-sectional study approved by the Research Ethics Committee of the Federal University of Mato Grosso do Sul, in Brazil (CAAE: 468.78621.8.0000.0021) with non-probabilistic sampling. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Recruitment was done through advertisements on social networks, pamphlets, and telephone invitations from contacts obtained at the Regional Hospital of Mato Grosso do Sul. This state hospital serves as a reference center for COVID-19 treatment and is located in Campo Grande, MS, Midwest of Brazil, on the border with Paraguay and Bolivia. Data were collected between April 2022 and February 2023, corresponding to the fourth and fifth waves of the COVID-19 pandemic.

The inclusion criteria were infants from birth to 18 months of age of both sexes assigned at birth who were exposed to SARS-CoV-2 during pregnancy with confirmations by molecular or serological diagnostic tests of the mother. Of 106 potential participants who were initially listed or contacted, 53 had unanswered telephone contact, 18 had pre-established neurological conditions or negative results for COVID-19, and 8 were older than 18 months were excluded; 8 refused to participate. Finally, 20 infants (and their mothers or fathers) participated.

Assessment tool

The Brazilian version of the AIMS, translated by Herrero and Masseti (16), was used to assess motor performance. The AIMS is a validated observational tool that evaluates the sequence of motor development and the control of antigravity muscles in prone, supine, sitting, and standing positions from birth to 18 months. The assessor observes the infant's performance and assigns a score of 1 for each observed item and 0 for each non-observed item, resulting in a maximum possible raw score of 58. AIMS raw scores can be converted into percentiles that indicate the infant's position compared to the age-matched sample by crossing the infant's age and score on a reference graph and table provided in the manual. The percentile is interpreted as follows: typical motor performance (above the 25th percentile curve), suspicious motor performance (between the 5th and 25th percentile curves), and atypical motor performance (below the 5th percentile curve) (10).

For exploratory comparative purposes, in this study, the Brazilian norm-referenced scores provided by Saccani *et al.* in 2016 (17) were adopted as normative AIMS data. These infants were assessed in the conventional in-person format before the pandemic period (17).

Procedures

All parents of infants signed an informed consent form to participate in the research, sent digitally via WhatsApp. Parents filled out a clinical and motor information form using the Google Forms platform to characterize the sample. Symptoms were classified according to the Brazilian Ministry of Health (18): asymptomatic (absence of symptoms); mild symptoms (cough, sore throat or runny nose, anosmia, ageusia, diarrhea, abdominal pain, fever, chills, myalgia, fatigue, and/or headache); moderate symptoms (persistent cough and fever, pneumonia without signs or symptoms of severity); severe symptoms (dyspnea or persistent chest pressure, tachypnea, hypoxemia, altered consciousness, dehydration, difficulty eating, myocardial injury, elevated liver enzymes, coagulation dysfunction, rhabdomyolysis, cyanosis, lethargy, seizures); and critical symptoms (sepsis, acute respiratory distress syndrome, severe respiratory failure, multiple organ dysfunction, severe pneumonia, need for respiratory support, and admissions to intensive care units).

On the day before the assessment, parents were provided with a 5-minute orientation video made available on a private link on the YouTube platform. In this video, parents were instructed by the physical therapist in charge (A.O.A.) regarding the assessment as follows: (I) infants should be dressed in diapers or body suits to facilitate their movements; (II) infants should be awake and active; (III) the environment should be safe, ensuring space to the infant spontaneously move and placing rugs on the floor to minimize the risk of falls and accidents; (IV) a toy of the infant's preference should be used to motivate the infant to move; (V) distractions [such as television (TV) and music] should be avoided during the assessment. A few hours before the assessment, parents received additional instructions via WhatsApp message on how to position the cell phone camera at a distance to fully allow observation of the infant on the screen. The physical therapist then contacted the parent at the scheduled time, which should not coincide with the infant's periods of sleep or hunger.

The AIMS was used according to the instructions outlined in its manual (10,16). The AIMS was applied via video call between the physical therapist and the infant's mother or father. This was done using the parents' preferred platform (Google Meet or WhatsApp).

At the beginning of the call, all previous instructions were reiterated to the parents to ensure that, even if they had not watched the orientation video, they would receive adequate instruction for the assessment. The assessments were recorded using an iPhone 11 and lasted approximately 30 minutes, during which the physical therapist provided direct guidance to the parents. This setup allowed parents to make queries about the infant's expected motor performance, and the physical therapist corrected the stimuli provided by the parents and the infant's positioning when necessary. Parents were informed via WhatsApp of their infant's motor performance after the intra- and interrater agreement analysis.

At the end of the data collection, a questionnaire on barriers and facilities was applied individually to the parents using the WhatsApp poll tool with a Likert scale (yes/no) based on Lima *et al.* (13) and Schlichting *et al.* (14). The questionnaire addressed the following questions: (I) whether they found it easy or difficult to understand and replicate the commands given by the physical therapist during the assessment; (II) whether they would be interested in participating in other remote assessments of their infants.

Finally, the physical therapist was required to use WhatsApp to list barriers, and facilities for guiding the parents during the video call. This included specific instructions, particularly concerning the infant stimuli and positioning, as well as the camera angle/view and lighting. All observers (first, second, and third authors) were required to list barriers and facilities to score the AIMS using the videos.

Assessors

The physical therapist conducted all assessments. Three assessors (A.O.A., A.B.D.N., A.J.R.), who were also trained in the application of the AIMS, independently scored all video recordings to analyze the inter-rater reliability. Subsequently, the assessors met to reach a consensus on the scoring. To assess intra-rater reliability, the three assessors re-scored 20% of the sample within a 6-month from the initial scoring.

Statistical analysis

The SPSS 23.0 software was used for statistical support. Frequencies, proportions, mean, standard deviation, and confidence intervals were calculated to describe the sample characteristics.

Table 1 Sample characteristics based on the questionnaire answered by parents of infants prenatally exposed to SARS-CoV-2 infection (n=20)

Characteristics	Values
Gestational age (weeks)	38.30±0.38
Age at assessment (months)	10.65±4.99
Maternal age (years)	
18–25	6 (30.0)
26–30	8 (40.0)
>30	6 (30.0)
Maternal education	
Incomplete high school	1 (5.0)
Complete high school	6 (30.0)
Incomplete higher education	4 (20.0)
Complete higher education	3 (15.0)
Postgraduate	6 (30.0)
Per capita income (R$/US$)*	R$1,010.00/US$194.20
Period of COVID-19 in pregnancy	
1st trimester	1 (5.0)
2nd trimester	7 (35.0)
3rd trimester	12 (60.0)
Maternal diagnostic test for COVID-19	
Molecular test (RT-PCR)	13 (65.0)
Molecular test (RT-PCR) and serological test	7 (35.0)
Maternal hospitalization for COVID-19	
Yes	6 (30.0)
No	14 (70.0)
Maternal symptoms related to COVID-19	
Asymptomatic	2 (10.0)
Mild symptoms	9 (45.0)
Mild and moderate symptoms	1 (5.0)
Mild and severe symptoms	3 (15.0)
Moderate and severe symptoms	1 (5.0)
Moderate and critical symptoms	4 (20.0)
Persistent symptoms in the infant	
Asymptomatic	17 (85.0)
Respiratory	1 (5.0)
Headache	1 (5.0)
Facial paralysis	1 (5.0)
Motor/behavioral changes in the infant	
None	18 (90.0)
Facial paralysis	1 (5.0)
Irritability	1 (5.0)

Data are presented as mean ± standard deviation or n (%). *, values based on the Brazilian minimum wage for the year 2022 and the quotation of 01/21/2023 (1 US$ =5.20 Real). SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; COVID-19, coronavirus disease 2019; RT-PCR, reverse transcription polymerase chain reaction.

One-sample binomial tests (probability 0.5) were used to analyze differences between the proportions of barriers and facilitators of the synchronous use of AIMS reported by the parents and assessors (easy × difficult), and between the proportions of infants with typical x atypical motor performance, pregnancy complications due to COVID-9 × no complications, and maternal COVID-9 vaccination × no vaccination.

To assess the inter- and intra-rater reliabilities based on the raw score of the AIMS in each posture, we used the intraclass correlation coefficient (ICC) with absolute agreement according to a two-factor mixed model. We employed the ICC classification proposed by Koo and Li (19), which includes good (0.75–0.90) and excellent (>0.90).

Descriptive statistics using means and standard deviation of the total raw scores and percentiles were used to describe the motor performance assessed with the AIMS. For exploratory purposes, *t*-tests were used to compare the mean of the total raw scores of the SARS-CoV-2-exposed infants with the mean of the raw scores of the Brazilian normative data (17) at matched ages.

Results

All 20 families who participated finished the assessment and questionnaire. The infant's assessment lasted a mean of 25±6.05 minutes; three infants required pauses due to irritability or crying. There were no technical failures during the assessments, such as loss of communication or internet connection issues.

Sample characterization

Table 1 presents the characteristics of the infants assessed.

The infants' mean gestational age was 38.30±0.38 weeks, and their mean age was 10.65±4.99 months (corrected for prematurity). Most of them were female (65.0%), born to married parents (70.0%), from the state of Mato Grosso do Sul, Brazil (n=18; 90.0%), and were exposed to SARS-CoV-2 during the 3rd trimester of gestation (60.0%).

Barriers and facilitators for parents and assessors

The proportion of parents who reported having found it easy (90.0%) to understand and replicate the commands during the online assessment using the AIMS was higher than the proportion of parents who found it difficult (10.0%) (P<0.001). The proportion of parents who reported that they would be willing to participate in further assessments of their infants using video calls (90.0%) was higher than the proportion of parents who would not be willing to (10.0%) (P<0.001).

The physical therapist in charge reported that guiding the parents during all video calls was easy. Concerning the AIMS scoring, all three assessors reported not encountering difficulty in most assessments. However, one noted that, in some cases, low lighting in the parents' camera or home environment made it challenging to visualize the infant perfectly.

Table 2 Inter-rater reliability

AIMS	ICC	f	95% CI	P
Total score	0.986	55.130	0.970–0.994	<0.001
Prone	0.991	78.114	0.980–0.996	<0.001
Supine	0.961	18.695	0.918–0.984	<0.001
Sitting	0.973	27.973	0.943–0.984	<0.001
Standing	0.865	5.037	0.734–0.942	<0.001

AIMS, Alberta Infant Motor Scale; ICC, intraclass correlation coefficient; f, *F* test; 95% CI, 95% confidence interval.

Inter-rater and intra-rater reliabilities

Inter-rater reliability was classified as excellent for the total score and AIMS postures (prone, supine, and sitting), except for standing, where reliability was classified as good (*Table 2*). Intra-rater reliability was classified as excellent for the total score and all assessed postures: prone, supine, sitting, and standing (*Table 3*).

Infants' motor performance

Table 4 presents the AIMS percentiles obtained by the SARS-CoV-2-exposed infants. The proportion of infants with typical motor performance (75.0%) was higher than the proportion of infants with suspicious/atypical motor performance (25.0%) (P=0.04). The proportion of mothers/infants who had experienced some perinatal complications related to COVID-19 infection was not statistically higher (65.0%) than that without complications (35.0%) (P=0.26). Of those who had pregnancy complications, only one (14.0%) had been vaccinated (P=0.12).

Table 5 shows the exploratory comparison between the mean raw scores obtained by the exposed infants and the reference values of the Brazilian normative sample by age. There were no differences between the groups for any of the ages.

Discussion

To our knowledge, this is the first study to assess the motor performance of infants exposed to COVID-19 using the AIMS via telemedicine. While most of the infants were

Table 3 Intra-rater reliability

AIMS	Rater 1		Rater 2		Rater 3	
	ICC (95% CI)	P	ICC (95% CI)	P	ICC (95% CI)	P
Total score	0.999 (0.990–1.000)	<0.001	0.997 (0.972–1.000)	<0.001	1.000 (0.995–1.000)	<0.001
Prone	1.000	–	0.986 (0.846–0.999)	0.003	1.000	–
Supine	1.000	–	0.989 (0.894–0.999)	0.002	1.000	–
Sitting	0.996 (0.957–1.000)	<0.001	0.992 (0.876–0.999)	0.002	0.996 (0.957–1.000)	<0.001
Standing	0.991 (0.877–0.999)	0.002	0.998 (0.983–1.000)	<0.001	0.998 (0.983–1.000)	<0.001

AIMS, Alberta Infant Motor Scale; ICC, intraclass correlation coefficient; 95% CI, 95% confidence interval.

Table 4 Data from motor assessments of each assessed infant, maternal vaccination, and maternal and infant perinatal complications

Infant	GA (weeks)	Age (months)	Total score	Percentile	Maternal infection (gestational trimester)	Maternal vaccination	Perinatal complications
1	39	14	58	90	Third trimester	After birth	–
2	41	5	29	>90	Third trimester	Second trimester	–
3	39	15	57	90	Third trimester	After birth	Fetal growth restriction
4	39	11	58	>90	Third trimester	After birth	Pre-eclampsia
5	34	18	58	90	Third trimester	After birth	Fetal distress
6	38	15	57	90	Third trimester	Third trimester	–
7	36	18	58	90	Second trimester	After birth	Fetal growth restriction
8	39	6	31	75–90	Second trimester	Second trimester	–
9	39	4	14	25–50	Second trimester	Before pregnancy	–
10	39	4	11	10–25	Second trimester	Not vaccinated	–
11	38	5	21	50–75	Third trimester	First trimester	–
12	39	8	52	>90	Third trimester	Second and third trimester	–
13	37	14	57	90	Second trimester	After birth	Need for maternal intubation Fetal distress
14	35	18	58	90	Third trimester	After birth	Premature birth
15	39	11	31	<5	Second trimester	Second trimester	Need for maternal intubation
16	39	9	27	<5	Second trimester	Third trimester	–
17	41	15	50	<5	Third trimester	Third trimester	–
18	38	6	22	10–25	Third trimester	Before pregnancy	–
19	39	9	48	50–75	First trimester	Before pregnancy	–
20	38	8	31	25–50	Third trimester	Before pregnancy	–

Age (months), infant age at the time of assessment in months; Total score, sum of AIMS supine, prone, sitting, and standing posture scores; Percentile, percentile classification of the infant; Maternal vaccination, gestational period in which the mother was vaccinated; Perinatal complications, clinical maternal or neonatal complications reported by mothers. GA, gestational age; AIMS, Alberta Infant Motor Scale.

female, we do not believe this impacted the results, as there are no reported differences in motor performance between sexes assessed using the AIMS (20).

Our results align with studies by Lima *et al.* (13) and Schlichting *et al.* (14), who demonstrated that the remote use of the AIMS in non-COVID-19 exposed infants exhibits excellent inter-rater reliability when parents are guided. These studies used standardized written instructions and voice messages to guide the parents (12,13). In our study, one key difference was the instructions being delivered to parents in video format, recorded by the physical therapist. In addition, real-time instructions were provided on the stimuli parents could provide to the infant to facilitate posture transfers during the video call assessment. We believe that these guidance options were helpful for parents, especially in cases where there may be educational limitations. This is particularly important in regions concerning illiteracy rates, such as Brazil, where 6.6% of the population aged 15 years or older cannot read or write (21). In our study, applying the AIMS through synchronous video call meetings allowed for the necessary corrections, enhancing the analysis of assessed aspects. It also facilitated guidance during the assessment and necessary handling in a simple and didactic manner. We emphasize the need to improve technological access for families to enable the widespread adoption of telemedicine in the daily lives of the

Table 5 Exploratory comparisons of mean values and standard deviations of total AIMS raw scores in each age between infants exposed to SARS-CoV-2 in the prenatal period assessed by telemedicine and infants in the Brazilian normative sample

Age (months)	Exposed sample (n)	Exposed (n=20)	Normative sample (n=717)	t	P
4	2	12.5±2.12	15.1±3.99	–0.91	0.37
5	2	25.0±5.66	19.4 ±5.51	1.42	0.16
6	2	26.5±6.36	23.9±7.69	0.47	0.64
8	2	41.5±14.84	35.7±8.96	0.89	0.38
9	2	37.5±14.85	39.6±8.61	–0.34	0.73
11	2	44.5±19.09	48.9±5.4	–1.03	0.31
14	2	57.5±0.71	56.0±3.01	0.68	0.50
15	3	54.7±4.04	57.0±2.08	0.51	0.61
18	3	58.0±0	57.9±0.48	0.50	0.62

t, *t*-test (for exploratory purposes only). AIMS, Alberta Infant Motor Scale; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

general population, particularly those with low income and limited education.

Interestingly, we observed that 86% of the cases involving perinatal complications (e.g., fetal growth restriction, pre-eclampsia, fetal distress, and need for orotracheal intubation) in our sample had not received a vaccine against SARS-CoV-2. This might support findings suggesting that COVID-19 vaccination before conception or as early as possible during pregnancy can decrease the rates of perinatal complications (22,23). However, this observation should be considered cautiously, as investigating this relationship was merely exploratory in this study.

Regarding the motor performance assessed by the AIMS, we did not observe differences between infants exposed to SARS-CoV-2 and the reference values for Brazilian infants assessed conventionally before the pandemic. In studies that assessed neurological abnormalities with the Prechtl General Movements Assessment (GMA), researchers found reduced motor repertoire in infants at 3–5 months post-term who were prenatally exposed to SARS-CoV-2 compared to concurrent or pre-pandemic unexposed infants (6,7). According to the results in our sample, gross motor skills assessed in a remote synchronous mode by the AIMS were not affected by prenatal exposure to COVID-19.

We emphasize the factors that may have contributed to minimizing the potential adverse effects of maternal infection on the motor performance of exposed infants: mothers with mild symptoms during the infection, associated with a low risk of gestational and developmental problems (24,25); new variants of SARS-CoV-2, with decreased severity due to the evolution of the virus's pathogenicity (26); and, finally, infection in the third trimester of pregnancy when although COVID-19 infection can lead to inflammatory responses in placental tissue (27), it also triggers protective immune responses (28). We suggest that gestational SARS-CoV-2 infection, whether through direct or indirect mechanisms, did not affect the motor performance assessed by the AIMS in the infants of this study. This should be interpreted cautiously, as our design allowed only an exploratory analysis of this issue.

We acknowledge that the study's external validity is limited because it did not include a representative sample of infants prenatally exposed to SARS-CoV-2, and it compared infants with a normative sample from a different, non-pandemic period, with a much larger sample. These aspects should be improved in future research. However, this study expands our understanding of the application of synchronous telemedicine in assessing infant motor development and supports this approach as an important tool when social distancing is needed. Additionally, it provides novel insights into the clinical characteristics of infected pregnant women and the motor performance of infants with intrauterine exposure to COVID-19. In future research, monitoring different aspects of infants prenatally exposed to SARS-CoV-2, such as neurological and behavioral outcomes, will be valuable to determine the real impact of gestational COVID-19 on child development.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Research Ethics Committee of the Federal University of Mato Grosso do Sul, in Brazil (CAAE: 468.78621.8.0000.0021) and the informed consent was obtained from all parents of infants.

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