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Effects of the COVID-19 Lockdowns on Gross Motor and Fine Motor Neurodevelopment in Toddlers

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ABSTRACT

Aim: To investigate possible differences in neurodevelopment between lockdown-exposed and non-exposed 18-month-old toddlers in Sweden.

Methods: Data were extracted from the prospective NorthPop Birth Cohort Study in Sweden. Neurodevelopment was assessed using the Ages and Stages Questionnaire Third Edition (ASQ-3) and a clinical routine evaluation at the child health care centre for additional validation. Statistical analyses were performed using IBM SPSS Statistics.

Results: More lockdown-exposed toddlers fell below the cut-off score on the ASQ-3 "Gross motor function" assessment at 18 months, compared to the pre-lockdown category (5.1% vs. 3.6%, adjusted $p = 0.002$). Conversely, fewer lockdown-exposed toddlers failed the fine motor task "Can draw scribble" versus the pre-lockdown category (1.4% vs. 2.4% adjusted $p = 0.014$).

Conclusions: Toddlers who were lockdown-exposed had lower gross motor function but were more successful in the fine motor task at 18 months.

1 | Introduction

The COVID-19 pandemic had a rapid and significant impact on the world. During this time, a lot of people were experiencing changes to their employment, social relationships, and economic situation [1]. The first case of COVID-19 in Sweden was reported in January 2020 [2] and was shortly followed by national societal adaptations. These included areas with mandatory facemask requirements, recommended limited social interactions outside of the close family, and recommendations to work from home [3]. The degree to which lockdowns were imposed on the public varied greatly between countries. Some enforced nationwide quarantines with full restrictions to leave home, which consequently meant less time socialising with people outside of family and being outside [4]. The lockdowns in Sweden, however, were less intense than those in other European countries. In a Swedish article from 2023, the degree of lockdown stringency estimated with the Stringency index showed that Sweden had the lowest score compared to 14 other European countries [5]. The degree of lockdown in Sweden also relied more on voluntary measures as opposed to mandatory restrictions [5]. Preschools also remained open for attendance.

Infants and toddlers (0 months to 2 years) are dependent on their parents for their physical, emotional, and social development [6]. Children require their emotional and physical needs to be met

Abbreviations: ASQ-3, Ages and Stages Questionnaire Third Edition; BMI, Body mass index; COVID-19, Coronavirus Disease 2019; SARS-CoV-2, Severe Acute Respiratory Syndrome Coronavirus 2.

Summary

- This study examines the neurodevelopment of 18-month-old toddlers in Sweden exposed to COVID-19 lockdowns, with previous research on the topic having shown inconsistent results.
- Results showed lower gross motor function in lockdown-exposed toddlers but better performance in fine motor tasks.
- The findings highlight both positive and negative impacts of lockdowns on toddlers, providing further insight into how external factors may influence neurodevelopment during early childhood.

to develop, and are positively impacted by stable and consistent parents [6, 7]. Conversely, exposure to stress and adverse experiences can harm the child's natural development [7].

Considering that the lockdowns changed many people's work and social lives [8], it could have affected the children growing up during this period as well. A study from 2022 found that toddlers were exposed to more screen time under lockdown compared to pre-lockdown [9]. A Chinese study from 2020 reported that over 50% of respondents rated their psychological impact of the outbreak of COVID-19 as moderate or severe [10]. Psychological stress can in turn negatively affect fetal brain development and pregnancy outcome [11]. A few relatively small studies have suggested that the COVID-19 lockdowns may have impacted neurodevelopment negatively among infants and young children [12, 13]. To evaluate the neurodevelopment impact of lockdowns, researchers have used validated screening instruments for neurodevelopment such as the Ages & Stages Questionnaires Third Edition (ASQ-3). Recent studies on the topic of COVID-19 lockdowns on the neurodevelopment of toddlers have shown inconsistent results [13–15]. Thus, prompting the need for more research. The study objective was to investigate possible differences in neurodevelopment between lockdown-exposed and non-exposed 18-month-old toddlers in Sweden. This study focuses on lockdown effects on neurodevelopment, not the COVID-19 virus itself.

2 | Material and Methods

2.1 | Study Design and Population

To address the research question, data were extracted from the prospective, population-based NorthPop Birth Cohort Study in Västerbotten, which so far includes more than 9000 families. Extensive data on health, socioeconomy and lifestyle is collected from pregnancy until 7 years of age, including repeated web questionnaires and linked register data [16].

Since 2016, pregnant women have been recruited to NorthPop at the time of the routine ultrasound examination at 14–24 weeks of pregnancy. Inclusion criteria are (1) viable pregnancy between 14 and 24 weeks of gestation, (2) pregnant women aged 18 years or older, (3) ability to understand Swedish, and (4) a plan to give birth and stay in the region of Västerbotten for the foreseeable future. Individual informed consent was given by the parents [16]. The women who did not fit the four criteria listed above or did not wish to participate were excluded.

The NorthPop project is approved by the Swedish Ethical Review Authority in written consent with diary numbers 2014-224-31 and 2015-175-31 M.

3 | Data Collection

3.1 | Definition of Study Categories

Children born between September 2016 and August 2018 were included and considered the "non-exposed" category. Children born between June 2019 and March 2021 were included and considered the lockdown-exposed category. These group definitions were made so the lockdown-exposed category had lived at least 9 months out of the first 18 months of life in the lockdown period (March 2020–December 2021). In contrast, the non-exposed category had not been exposed to lockdowns at 18 months of age. With this divide, the lockdown category had spent at least half of their life in lockdown conditions at the time of testing, whereas the non-exposed group had spent no time under lockdown conditions. The category definitions could also ensure no overlap. The children in the NorthPop cohort who did not fit the exposed category (minimum 9 months exposure) nor the non-exposed category criteria (any time spent in the chosen lockdown period) were excluded from the analysis. The flowchart (Figure 1.) shows the process of inclusion in the study.

3.2 | The Ages and Stages Questionnaire (ASQ-3)

As a measure of neurological development, we used Ages & Stages Questionnaires, Third Edition (ASQ-3), which was filled in by the parents once when the child was 18 months old. The questionnaire was translated into Swedish with no other purposeful alterations. The ASQ-3 is a validated instrument which includes questions on five different domains of child development: communication, gross motor skills, fine motor skills, problem-solving, and personal-social skills. In each category, the participant could score between 0 and 60 points and by combining the five categories a total of 300 points could be achieved [17]. The cut-off value for each domain was set at < -2 SD, based on the American ASQ-3 cut-off values.

3.3 | The Child Healthcare Center Evaluation

A clinical routine neurodevelopmental evaluation at the child healthcare centre was performed on all 18-month-old toddlers, as part of the national routine checkup performed by child healthcare physicians and/or nurses. It consists of tick boxes based on reported or observed behaviours in eight different tasks. One Gross motor task, "Can walk without support". Two fine motor tasks "Builds towers out of 2-3 building blocks" and "Can draw scribbles". With the "Can draw scribbles" task, the child is given crayons and paper, and requires them to make dots and lines on the paper. If the child is not able to draw with the crayon, the task skill is noted as "Cannot perform". Further,

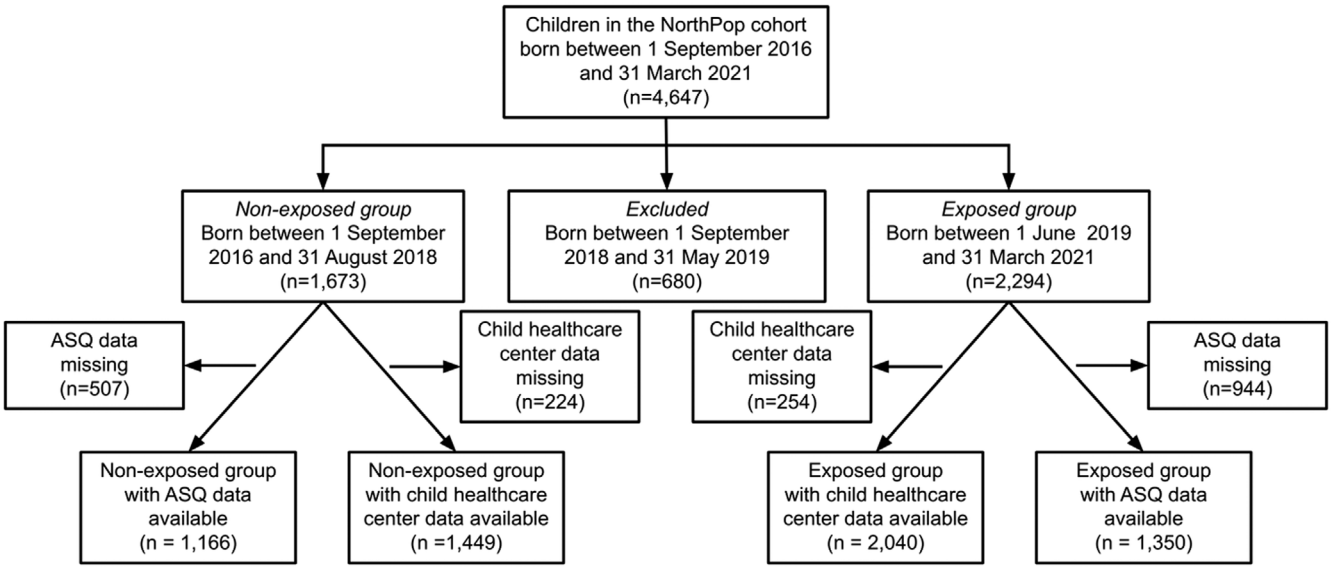

FIGURE 1 | Study participants divided by lockdown exposure.

there are five more tasks testing communication skills: "Speaks 8-10 words", "Can understand more than 8-10 words", "Hide and find game", "Can point out body parts" and "Can go get items on demand" where most are self-explanatory. The "hide and find game" involves a physician or nurse concealing a toy in paper, while the child watches, and having them find it again. This should evoke curiosity and a striving in the child to get the toy. If the child does not understand the task or seems uninterested, the task skill is noted as "Cannot perform". For each of the tasks, the doctor (or nurse) writes "+" for "Observed skill", "M" for "Parent-Reported" skill and "–" if the child "Cannot perform" the task [18]. In the analyses, the "Observed" and "Parent-Reported" were combined.

3.4 | Background Information

Data on maternal body mass index (BMI), age at delivery, delivery mode and the child's gestational age, birth weight, head circumference at birth and sex (male/female) were obtained from The Swedish Pregnancy Register [19]. Information about breastfeeding occurrence at 18 months of age, the age of the child when they started preschool, and time spent outdoors was obtained from NorthPop questionnaires. Information about the parents' income was obtained from Statistics Sweden's Longitudinal Integrated Database for Health Insurance and Labour Market Studies (LISA).

Confounders or mediators with possible impact on neurodevelopment were considered, including: the mother's BMI at the routine ultrasound, the age of the mother at delivery and delivery mode (vaginal yes/no), gestational age at birth, birth weight, head circumference at birth and sex (male/female). Lastly, the following postnatal factors that could impact the child's development were considered: breastfeeding occurrence at 18 months of age and the age of the child when starting preschool.

3.5 | Data Analysis

Statistical analyses were performed using IBM SPSS Statistics (version 28, IBM Corp., Armonk, NY, USA). Descriptive statistics were first used to present and visualise the data. For continuous variables (maternal BMI, maternal age at delivery, birth weight, head circumference, gestational age at birth, age at preschool start), independent t-tests were performed to compare means. For binary variables (lockdown exposure, vaginal birth, infant sex, breastfeeding at 18 months), cross tabs with chi-square were applied. Linear regression analyses were used for analyses of associations between continuous variables and continuous outcomes (ASQ test scores). For binary outcomes (proportions below cut-offs for ASQ and failing child healthcare center tasks), logistic regression analyses were used. The threshold for significance (alpha) was set to 0.05. The exact method for each analysis is explained in footnotes to the corresponding table.

The multivariable analyses were conducted using SPSS General Linear Model (GLM) for continuous outcome variables. Logistic regression analyses were used for binary outcome variables. Final models were created using the backwards stepwise procedure.

4 | Results

4.1 | Participant Background Information

The flowchart displays the number of participants in the study, both the exposed and non-exposed groups as well as the number of participants in each evaluation (Figure 1). A description of the study population is presented in Table 1. In the lockdown-exposed category, compared to the non-lockdown-exposed category, maternal BMI was higher (+0.4 units, mean 24.7 $p = 0.002$), breastfeeding occurrence at 18 months was higher (+3.2%, mean

8.8%, $p=0.006$) and age at preschool start was earlier (14.8 vs. 15.0 months, $p<0.001$). The household economic situation was measured using yearly disposable income per unit of consumption. There was no significant difference in income between the lockdown-exposed and non-exposed groups (Table 1).

Lockdown-exposed (vs. non-exposed) 18-month-olds spent more time outdoors in a day on weekdays, 3.13 (±1.84) hours vs. 2.93 (±1.86) hours; $p=0.004$. The lockdown-exposed children also spent more time outdoors on weekends, 3.11 (±1.82) hours vs. 2.95 (±1.73) hours per day; $p=0.019$. Average time spent outdoors in a day on weekdays and weekends combined also ended up being higher in the lockdown-exposed category, with a daily average of 3.13 (±1.68) hours compared to 2.94 h (±1.71) $p=0.003$.

4.2 | Ages and Stages Questionnaires (ASQ)

The results from the ASQ questionnaire are presented in Table 2. Lockdown exposure was significantly and negatively related to gross motor function ($p=0.019$). Table 3 shows the proportions (%) of participants scoring below the cut-off value in each group. Lockdown-exposed toddlers had a higher, although non-significant, risk of scoring below the cut-off for "Gross motor function" compared with the non-exposed group

TABLE 1 | Description of the study population.

	N	Missing	Mean score	SD	Min-Max	Lockdown-exposed mean/%	Lockdown non-exposed Mean/%	*p*
Maternal BMI (kg/m^2)	3655	82	24.7	4.5	15.4–45.9	24.9 (*n*:2111)	24.5 (*n*:1544)	0.002
Maternal age at delivery (years)	3737	0	30.8	4.3	18–45	30.7 (*n*:2145)	30.8 (*n*:1592)	NS
Vaginal birth	3730	7	78%			76.8% (*n*:2139)	79.5% (*n*:1591)	NS
Birth weight (g)	3734	3	3510	554	551–5380	3498 (*n*:2145)	3526 (*n*:1592)	NS
Gestational age at birth (weeks)	3737	0	39.6	1.8	22.4–42.8	39.5 (*n*:2145)	39.7 (*n*:1592)	NS
Head circumference (cm)	3732	5	34.9	2.3	20–64	34.9 (*n*:2145)	34.9 (*n*:1592)	NS
Sex (Female)	3737	0	48.6%			49.1% (*n*:2145)	47.9% (1592)	NS
Breastfeeding at 18 months (Yes)	2351	1386	8.8%			10.4% (*n*:1227)	7.2% (*n*:1124)	<0.006
Age at preschool start (months)	2238	1499	14.9	1.8	1–19	14.8 (*n*:1086)	15.0 (*n*:818)	<0.001
Disposable income (1000 SEK)	3734	3	229	162	96–828	231 (*n*:2142)	228 (*n*:1592)	NS

Note: *p*-value was significant with *p*-value <0.05. *p*-value >0.05 was marked NS for non-significant. Independent *t*-test was used for comparing means, while chi-square was used for categorical variables.
Abbreviations: Mean score, total mean value in the variable; Mean/%, mean value divided by the lockdown-exposed or non-exposed group *or* percentage of binary value; SD, standard deviation.

TABLE 2 | Ages and Stages Questionnaire-3 scores, in total and by lockdown exposure.

ASQ-3 18-month-olds	*N*	Mean score	SD	Cut-off	Non-exposed mean score	Exposed mean score	*p*
Communication	2516	37.8	12.7	15	37.9	37.8	NS
Gross motor	2516	56.5	7.4	40	56.8	56.1	0.019
Fine motor	2516	54.3	7.8	35	54.4	54.2	NS
Problem-solving	2516	43.4	10.8	20	43.4	43.5	NS
Personal-social	2516	48.1	8.3	30	48.0	48.2	NS

Note: In each category 0–60 points can be made. *p*-value was significant with *p*-value <0.05. *p*-value >0.05 was marked NS for non-significant. Independent t-test was used for comparing means, while chi-square was used for categorical variables. Number of participants in the non-exposed group: 1166. Number of participants in the exposed group: 1350.
Abbreviations: Cut-off, Cut-off value for each category; Mean score, Total mean value in each category; SD, Standard deviation.

(5.1% vs. 3.6%, $p = 0.066$) (Table 3). Associations between ASQ-3 scores and possible explanatory factors are shown in Table 4. Significant positive associations in several ASQ domains were observed for birth weight, gestational age, head circumference and female sex. Significant negative associations were observed for maternal BMI and maternal age.

4.3 | Child Healthcare Centre Evaluation

Results from the neurodevelopmental evaluations at the child healthcare center are presented in Table 5, for the whole population and by lockdown exposure. For the "Can draw scribbles" task, a significantly higher proportion of lockdown-exposed toddlers could perform the task compared with non-lockdown-exposed ($p = 0.023$). The association between the confounders and the child healthcare centre task is shown in Table 6.

4.4 | Multivariable Analyses

For the two outcome variables where lockdown exposure was a statistically significant predictor (i.e., "Gross motor function"

TABLE 3 | Ages and Stages Questionnaire-3 and proportion of children below the cut-off value, by lockdown exposure.

ASQ-3 18-month-olds	Cut-off value	Exposed *n* (%)	Non-exposed *n* (%)	*p*
Communication	15	64 (4.7%)	57 (4.9%)	0.863
Gross motor	40	69 (5.1%)	42 (3.6%)	0.066
Fine motor	35	58 (4.3%)	58 (5.0%)	0.419
Problem-solving	20	67 (5.0%)	56 (4.8%)	0.853
Personal-social	30	61 (4.5%)	55 (4.7%)	0.813

Note: *p*-value was significant with *p*-value < 0.05. *p*-value > 0.05 was marked NS for non-significant. Chi-square was used for categorical variables. The total number of participants in each category is 2516. The number of participants in the exposed category is 1350. The number of participants in the non-exposed category is 1166.
Abbreviations: *n*, number of participants; (%), percentage of participants in each timeframe with scores below the cut-off value rounded up to the closest 0.0 decimal.

TABLE 4 | Associations between background factors and Ages and Stages Questionnaire-3 scores.

	Communication	Gross motor	Fine motor	Problem-solving	Personal-social
Birth weight	$p = 0.002$ $r = 0.053$	$p < 0.001$ $r = 0.138$	$p < 0.001$ $r = 0.131$	$p < 0.001$ $r = 0.103$	$p < 0.001$ $r = 0.083$
Gestational age	$p < 0.001$ $r = 0.128$	$p < 0.001$ $r = 0.171$	$p = 0.001$ $r = 0.194$	$p < 0.001$ $r = 0.155$	$p < 0.001$ $r = 0.107$
Head circumference	NS	$p < 0.001$ $r = 0.114$	$p < 0.001$ $r = 0.093$	$p < 0.001$ $r = 0.130$	$p < 0.001$ $r = 0.069$
Sex (Female/Male)	$p < 0.001$ Female: 40.7 Male: 35.2	NS	$p = 0.012$ Female:54.7 Male:53.9	$p = 0.003$ Female: 44.1 Male: 42.8	$p < 0.001$ Female: 49.2 Male: 47.1
Breastfeeding at 18 months (Yes/No)	$p = 0.022$ Yes:39.8 No:37.7	NS	NS	$p < 0.001$ Yes: 45.9 No: 43.2	$p = 0.027$ Yes: 49.3 No: 48.0
Preschool age start	NS	$p = 0.002$ r = −0.077	NS	NS	$p = 0.047$ r = −0.050
Maternal BMI (kg/m^2)	$p < 0.001$ $r = -0.065$	NS	$p = 0.028$ $r = -0.044$	$p = 0.032$ $r = -0.043$	NS
Maternal age at delivery (years)	NS	$p = 0.023$ $r = -0.045$	$p < 0.001$ $r = -0.069$	NS	$p < 0.001$ $r = -0.088$
Vaginal delivery (Yes/no)	NS	NS	NS	$p < 0.001$ Yes: 43.8 No:42.2	$p < 0.001$ Yes:48.5 No: 46.8
Disposable income (per 1000 SEK)	NS	NS	NS	NS	NS

Note: For independent *t*-test analyses, mean values are presented. Number of participants = 2516.
Abbreviations: NS, non-significant ($p \geq 0.05$); *r*, regression coefficients from regression analyses.

TABLE 5 | Child healthcare centre tasks and child performance, in total and by lockdown exposure.

	Observed *n* (%)	Parent reported *n* (%)	Cannot perform *n* (%)	Cannot perform task exposed/non-exposed (%) (*p*-value)
Gross motor "Can walk without support"	3391 (97.2%)	61 (1.7%)	37 (1.1%)	1.1%/1.0% (NS)
Fine motor "Builds towers out of 2–3 building blocks"	3073 (88.1%)	352 (10.1%)	64 (1.8%)	1.5%/2.3% (NS)
Fine motor "Can draw scribbles"	2898 (83.1%)	528 (15.1%)	63 (1.8%)	1.4%/2.4% (0.023)
Communication "Speak 8–10 words"	2288 (65.6%)	700 (20.1%)	501 (14.4%)	14.6%/14.1% (NS)
Communication "Can understand more than 8–10 words"	2867 (82.2%)	597 (17.1%)	25 (0.7%)	0.7%/0.7% (NS)
Communication "Hide and find game"	2686 (77.0%)	763 (21.9%)	40 (1.1%)	1.3%/0.9% (NS)
Communication "Can point out body parts"	2449 (70.2%)	816 (23.4%)	224 (6.4%)	7.0%/5.7% (NS)
Communication "Can go get items on demand"	2685 (77.0%)	750 (21.5%)	54 (1.5%)	1.5%/1.6% (NS)

Note: Calculations were made using chi-square. Total number of participants: 3489. Total number non-exposed: 1449. Total number exposed: 2040.
Abbreviations: *n*, number of children; NS, non-significant ($p \geq 0.05$); %, the proportion of children in each group.

and the "Can draw scribbles" task), multivariable analyses were performed to provide adjusted *p*-values and to assess possible effects of confounders. For each of the two outcomes, all confounders from Table 1 were initially included, and a backwards stepwise procedure was performed to refine into a final model. Each of the three variables, "Gross motor function" (binary and continuous version) and "Can draw scribbles" (binary version), was analysed separately with the confounders. For the continuous variable Gross motor function, lockdown exposure remained significant in the final model, with an adjusted $p = 0.003$ and $r = -1.102$. The final model also included gestational age at birth ($p < 0.001$, $r = 0.587$) and maternal age at birth ($p = 0.022$, $r = -0.099$). For the binary "Gross motor function below cut-off" variable, lockdown exposure was significant in the final model with an adjusted $p = 0.002$ and an OR = 2.298. The final model also included gestational age at birth ($p < 0.001$, OR = 0.807) and age at preschool start ($p = 0.44$, OR = 1.145). For the binary "Can draw scribbles" variable, lockdown exposure remained significant with an adjusted ($p = 0.014$ and OR = 1.872). The final model also included vaginal birth ($p = 0.016$, OR = 0.525), birth weight ($p < 0.001$, OR = 1.001) and sex ($p = 0.005$, OR = 0.470). Disposable income did not remain a significant predictor in either the "Gross motor function" task or the "Can draw scribbles" task in the final model.

5 | Discussion

Lockdown-exposed toddlers presented a lower mean score for gross motor function. In contrast, a higher proportion of lockdown-exposed toddlers were able to perform the fine motor task of drawing scribbles. We did not find a significant difference between the groups regarding communication skills, problem-solving or personal-social skills.

Comparing these results to previous research, a New York-based study found lower scores on three ASQ domains, gross motor, fine motor and personal-social, in lockdown-exposed children at 6 months [13]. The New York study included 255 infants, and the authors suggested the ASQ difference was due to upbringing during lockdown conditions and not related to an in utero virus infection [13]. Another study based in China, including 831 children, contradicted these results and showed no difference in 6-month-old children [14]. Instead, the China study found a lower score in fine motor and communication in 1-year-olds [14]. Moreover, a meta-analysis on COVID-19 and the neurodevelopment of infants found that lockdown-exposed 1-year-olds were more prone to communication delays [15]. It also found an increased risk of fine motor delays if there had been a maternal COVID-19 infection while the child was in utero [15]. The meta-analysis included studies from the US, Canada, China and Kuwait and had a total number of 11 438 participants. The meta-analysis, however, did not find any difference in the overall risk of delayed neurodevelopment [15]. A study from Canada using ASQ-3 scores found that lockdown-exposed children aged 24 months had better problem-solving skills. They were also less likely to fall below the cut-off value in the same category. However, they were more likely to fall below the cut-off value in the personal-social category [20].

TABLE 6 | Association between background factors and performance on the Child Healthcare Centre tasks.

	Gross motor "Can walk without support"	Fine motor "Builds towers out of 2–3 building blocks"	Fine motor "Can draw scribble"	Communication "Speaks 8–10 words"	Communication "Can understand more than 8–10 words"	Communication "Hide and find game"	Communication "Can point at body parts"	Communication "Can go get items on demand"
Birth weight	$p<0.001$ OR = 1.001	$p<0.001$ OR = 1.001	$p<0.001$ OR = 1.001	NS $p=0.090$	$p=0.003$ OR = 1.001	NS $p=0.058$	$p=0.026$ OR = 1.000	$p<0.001$ OR = 1.001
Gestational age	$p<0.001$ OR = 1.276	$p<0.001$ OR = 1.260	$p<0.001$ OR = 1.262	$p<0.001$ OR = 1.091	$p<0.001$ OR = 1.271	NS $p=0.061$	$p<0.001$ OR = 1.154	$p<0.001$ OR = 1.341
Head circumference	$p=0.004$ OR = 1.086	$p=0.003$ OR = 1.078	$p<0.001$ OR = 1.084	NS $p=0.114$	NS $p=0.209$	NS $p=0.808$	NS $p=0.984$	$p<0.001$ OR = 1.090
Sex (Female/Male)	NS $p=0.330$	$p=0.038$ 1.4%[c]/2.3%	$p=0.006$ 1.2%/2.4%	$p<0.001$ 10.3%/18.2%	NS $p=0.093$	NS $p=0.633$	$p<0.001$ 3.4%/9.3%	$p=0.022$ 1.1%/2.0%
Breastfeeding at 18 months (Yes/No)	NS $p=0.878$	NS $p=0.725$	NS $p=0.666$	NS $p=0.165$	NS $p=0.211$	NS $p=0.878$	NS $p=0.237$	NS $p=0.081$
Preschool age start	NS $p=0.083$	NS $p=0.692$	NS $p=0.536$	NS $p=0.058$	NS $p=0.887$	NS $p=0.067$	NS $p=0.457$	NS $p=0.224$
Mother BMI at admission to maternity centre	$p=0.017$ OR = 0.929	NS $p=0.383$	NS $p=0.954$	NS $p=0.098$	NS $p=0.112$	NS $p=0.724$	$p=0.001$ OR = 0.956	NS $p=0.229$
Mothers age at birth	$p=0.018$ OR = 0.916	NS $p=0.652$	NS $p=0.699$	$p<0.001$ OR = 0.961	NS $p=0.694$	NS $p=0.802$	NS $p=0.178$	NS $p=0.227$
Vaginal delivery (Yes/No)	$p=0.007$ 0.8%/1.9%	$p=0.022$ 1.5%/2.8%	$p<0.001$ 1.3%/3.3%	NS $p=0.061$	$p<0.001$ 0.4%/1.6%	NS $p=0.681$	$p<0.001$ 5.6%/9.2%	$p=0.013$ 1.3%/2.5%
Disposable income (per 1000 SEK)	NS $p=0.305$	NS $p=0.066$	NS $p=0.971$	NS $p=0.518$	NS $p=0.127$	NS $p=0.057$	$p=0.013$ OR = 1.255	$p=0.010$ OR = 1.677

Note: p-value was significant with p-value <0.05. p-value >0.05 was marked NS for non-significant. Calculations were made using chi-square for categorical confounders and binary logistic regression for continuous confounders. The number of participants was 3489 across all categories, except for the variables Mothers BMI, Preschool age start, and Breastfeeding at 18 months, which ranged from 912 to 3416.
Abbreviations: OR, odds ratio; %, proportion of participants who could not perform the task domain in a binary variable.

The inconsistency between study results could be due to several factors. Since the lockdown-induced restrictions between nations were not the same, the impact on the children and parents varied. The amount of time spent in the lockdown period also differed between studies, some including participants who had only spent 2.5 months in lockdown conditions [14]. The ages of the children included were not the same either, ranging from 6 months to 2 years or more.

To explain the lockdowns' effect on children, we must consider the general impact on the parents. For people with pre-lockdown vulnerabilities, including poor socioeconomic situations and mental health issues, the lockdowns were only adding to the burden. During the COVID-19 lockdowns, more people entered poverty worldwide [21]. Poverty can result in mental health issues and increase stress, which in turn can lead to less attentive parenting [21]. Poverty can also cause food scarcity and a lack of adequate nutrition [22]. These surrounding factors imposed by the lockdowns could be the reason for delays in neurological development. However, the income in our study population was similar to the Swedish national average [23]; there was no significant difference in income between lockdown-exposed and non-exposed participants, and adjusting for income did not affect the results of the study. This suggests that socioeconomic status is unlikely to explain the findings in our study.

We also found that the population demographic changed slightly between the groups. Lockdown-mediated effects were increased mean BMI of the mothers and increased breastfeeding occurrence at 18 months and changes in delivery mode. Neither breastfeeding occurrence at 18 months or maternal BMI was significantly associated with the gross motor task (Table 4 and multivariable analyses). For the "Can draw scribbles" task, maternal BMI was not significant, however, breastfeeding occurrence did remain significant in the multivariable analyses. Overall, it is an interesting incidental finding potentially reflecting reduced physical activity effects on maternal BMI during lockdowns and the impact of remote work on extended breastfeeding duration.

Vaginal delivery was not significantly associated with the ASQ Gross motor task. It was, however, significantly linked to the Can draw scribbles task (Table 6 and multivariable analyses) hinting at a possible link between delivery mode and fine motor function. A study from 2021 found that preschool fine motor skills and vaginal delivery mode were related [24]. However, more research is needed to provide a definitive connection.

Neurological skills should naturally improve with age and each domain develops at a different pace. Communication delays are not uncommon in early infancy [25]. The age at which participants were included in the studies could therefore have impacted the results. Fine motor skills delays were not found in this study. This could be due to more time spent refining fine motor skills in preschool. An environment which gives plenty of opportunities for both outdoor and indoor play can help to develop fine motor skills [26]. In this study, the lockdown-exposed toddlers spent more time outdoors and in preschool compared to the non-exposed toddlers. This could explain the lack of fine motor delays in the lockdown group which was evident in some other studies on the subject [13, 15]. Delays in personal-social skills were not found. In Sweden, more people were transitioning to working remotely part-time [27]. This could have led to more time being spent with the children, while parents worked from home. In our study population, the age at which the children started preschool was not substantially affected. Therefore, social interactions with other children at preschool were not much different to pre-lockdown. A report from The National Agency for Education in Sweden on the effects of the lockdowns on preschool operations found that the children had spent more time outdoors [28]. However, absences from preschool, both long and short-term, had increased drastically. This was assumed to be due to the lockdown restrictions put in place, not allowing children to participate in preschool activities if they presented with any sign of illness. This in turn could have impacted the results in this study, positively with more time outdoors and negatively with possibly more preschool absence.

In this study, we found lower gross motor function in lockdown-exposed toddlers. A review from 2022 showed an increase in screen time usage and more time spent sedentary among adults during the lockdowns [9]. Parents who are physically active are more likely to have children who engage in physical activity as well [29]. We speculated that the lockdown-exposed children had spent less time outdoors on gross motor activities and more time indoors on problem-solving activities like drawing. However, the lockdown-exposed children spent more time outdoors, thus invalidating this theory.

One strength of the study method is the large sample size. This increases the probability of the results being representative of the general population. Another strength is the comparison group having a similar number of participants, the same inclusion criteria, and the same population base, dating back years. We also used two assessment methods where one was performed with a healthcare professional, as opposed to only using the Ages and Stages Questionnaire, which has a risk of parent bias.

Weaknesses of the study include the variety of impacting mediators which makes causality difficult. As usual with observational studies, there are likely several possible residual confounders with an impact on the outcome not yet regarded. Due to the lack of validated Swedish ASQ-3 cut-off values, US cut-off values were used, which could have impacted the results. In this study, the presence of COVID-19 infection in the mother or child was not examined. A study from 2024 found that neonates with confirmed SARS-CoV-2 infection presented a higher risk of developmental delays at 18–24 months of age [30]. Considering this, the post-viral effect on neurodevelopment could have impacted the results.

This study found that lockdown-exposed toddlers had decreased gross motor function and greater fine motor skills, yet the differences were small. For the time spent outdoors variable, the difference between the groups in minutes is small, and the clinical relevance is debatable. To examine if the negative impact on gross motor function persists over time, longitudinal follow-up is of importance. This study paves the way for further investigation into the lockdown impact on gross motor function, which appears to remain despite good socioeconomic status and adequate social interaction with peers and outside play. It also highlights the importance of preschool attendance, which could be interpreted as a protective factor against fine motor delays, even

in times of crisis. This in turn could be of interest when assessing public health policies and their impact on toddler development.

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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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