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**Long-term trajectories of social adjustment and
emotional/behavioral problems in pediatric post-acute COVID-19**

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Abstract

COVID-19 has been associated with adverse mental health outcomes in children. However, evidence regarding the long-term trajectories of post-acute symptoms remains limited. We examined long-term emotional and behavioral trajectories in children following COVID-19 infection. Eighty-four children (aged 6–16) with a confirmed COVID-19 were initially enrolled. Of

these, 69 completed the three-year follow-up assessment and were included in the present analyses. Parents completed assessments approximately three months post-infection, retrospectively rating their child's behavior preceding infection and during the two weeks prior to the post-COVID assessment. An age- and sex-matched control group ($n = 94$) completed identical assessments. The COVID-19 group was reassessed approximately three years post-infection. Results showed that the COVID group showed significant impairments in school functions, internalizing problems, conduct problems, irritability and focus in post-COVID conditions compared to pre-COVID baseline. At three-year follow-up, most impairments resolved to pre-COVID levels. However, prosocial functioning among females remained impaired. Additionally, longer time since infection correlated with fewer school function problems ($r = -0.26$, $p = 0.041$) and lower levels of internalizing symptoms ($r = -0.26$, $p = 0.038$). In conclusion, post-COVID-19 children exhibited marked post-acute impairments in school functioning, increased emotional and behavioral problems followed by heterogeneous recovery trajectories.

Keywords: Children, Emotional/behavioral impairment, Post-COVID trajectory, Mental health

1. Introduction

The outbreak of coronavirus disease 2019 (COVID-19) pandemic has caused profound and multifaceted impacts on the health and development of children and adolescents. Beyond the acute phase of infection, a

subgroup of individuals experiences a persistent syndrome variably termed as post-COVID-19 condition (PCC), post-acute sequelae of COVID (PASC) or long COVID. This condition is generally defined by the onset of symptoms within three months of acute infection, with persistence for at least two months and no alternative explanatory diagnosis ¹. In pediatric populations, commonly reported manifestations include fatigue, respiratory problems, headaches, muscle pain, gastrointestinal discomfort, and cognitive impairments. Neuropsychiatric symptoms include anxiety, depression, mood instability, irritability, concentration difficulties, and sleep disturbances, which can substantially disrupt children's daily activities, academic performance, and social engagement ².

Longitudinal evidence underscores the persistence of these sequelae. A 3-year prospective cohort study reported long COVID prevalence rates of 23.2% of children at 3 months, 13.2% at 6 months, 7.9% at 12 months, 6.1% at 18 months, and 7.1% at 24 months following infection in children, indicating a remarkable burden over time ³. The pathophysiology of long COVID is increasingly recognized as multifactorial, involving viral particles persistence, immune and complement system dysregulation, mitochondrial impairment, endothelial inflammation, autonomic nervous system dysfunction and microbiome dysbiosis ^{2,4}. Among these, the mechanisms most relevant to mental health outcomes include sustained systemic inflammation, central nervous system (CNS) abnormalities, and psychosocial stressors such as social isolation, quarantine measures,

educational disruptions². Emerging evidence suggests that persistent neuroinflammation and immune dysregulation may contribute to neuropsychiatric symptoms through prolonged cytokine release and microglial activation^{5,6}. Neuroinflammatory process may affect brain regions involved in emotional regulation, including the amygdala, hippocampus, hypothalamus, and cerebral cortex, while cytokine-mediated alterations in neurotransmitter signaling and neural circuitry have been associated with difficulties in attention, memory, and mood regulation^{6,7}. Given that childhood and adolescence represent critical periods for brain maturation and neural plasticity, COVID-19 infection during these developmental periods may lead to long-term alterations in neural circuitry with potential lifelong consequences⁸. Therefore, heightened clinical and public health awareness of post-COVID mental health sequelae in children and adolescents is crucial to facilitate early identification, targeted intervention, and long-term support.

Research examining mental health trajectories following COVID-19 infection has yielded heterogeneous and inconsistent findings, indicating substantial variability across populations, methodological approaches, and temporal follow-up periods. For example, a longitudinal, prospective cohort study showed that depression, anxiety, and fatigue worsened at 2-3 years than at 6 or 12 months after infection in adults who had been hospitalized due to COVID-19⁹. Another study reported that depression improved significantly over time while anxiety and insomnia remained largely stable

in adults ¹⁰. A large-scale retrospective study of 13 million youths demonstrated that SARS-CoV-2 infection was significantly associated with increased risk of new-onset mental disorders within two years ¹¹. A cross-sectional study of 322 pediatric patients found that long COVID symptoms affected 60% of children at onset, declining to 22% by 3-5 months post-infection, with headache, fatigue, and anosmia being most common ¹². Notably, younger children (1.5-5 years) exhibited significant internalizing problems, while among older children (6-18 years), anxiety and post-traumatic stress were the predominant psychological sequelae ¹². A cohort study of 81 pediatric patients with long COVID found that more than half initially presented with moderate-to-severe functional impairment, predominantly characterized by fatigue or cardiopulmonary symptoms. Despite this substantial early burden, 78% of patients improved within approximately 6 months ^{13,14}.

Although previous studies have provided important evidence regarding long-term mental health outcomes following pediatric COVID-19 infection, less is known about the long-term trajectories of specific social adjustment, emotional, and behavioral domains assessed using detailed psychosocial measures. The present study aimed to investigate emotional and behavioral problems in children following COVID-19 infection, with longitudinal follow-up extending to approximately three years after infection to characterize long-term mental health outcomes. A comparison group of healthy control children also underwent assessment during the pandemic period. We

hypothesized that children with a history of COVID-19 infection would exhibit greater emotional and behavioral impairments compared with their pre-infection baseline and healthy controls, and that the majority of symptoms would subsequently return to the pre-COVID level in the three-year follow-up assessment.

2. Methods

2.1. Participants

This longitudinal cohort study initially enrolled 84 children aged 6-16 with COVID-19 infection confirmed by clinical physicians at the Pediatric COVID-19 Integrated Clinic of National Taiwan University Children's Hospital from July 1, 2022, to October 31, 2023. Participants were referred to the clinic by pediatricians for evaluation of persistent or atypical symptoms potentially related to prior COVID-19 infection. Of the 84 enrolled participants, 69 completed the three-year follow-up assessment and were included in the present analyses, corresponding to a retention rate of 82.1%. Among these 69 participants, 26 (37.7%) had been hospitalized during the acute phase of COVID-19 infection.

All participants completed the first assessment approximately three months after infection using parent-reported questionnaires, which evaluated the child's emotion and behavior over the preceding two weeks (post-COVID) as well as retrospectively assessed emotion and behavior prior to infection (pre-COVID). A follow-up assessment was conducted approximately three years after infection (follow-up). During the same

pandemic period, age- and sex-matched healthy controls without a history of COVID-19 infection were recruited from the same school districts as the children with COVID-19 infection. Matching was conducted at the group level to ensure comparable age and sex distributions between two groups. Healthy controls underwent the same assessments as the COVID group at a single time point.

All participants had no current or lifetime history of any major psychiatric disorder, nor any neurological disorder or major systemic medical condition. Participants were recruited after schools in Taiwan had returned to regular in-person instruction and major pandemic-related restrictions had been lifted. Demographic of the COVID and control group are presented in Table 1.

2.2. Procedure

The study was approved by the Research Ethics Committee of National Taiwan University Hospital before implementation. All participants and their parents read and signed the informed consent. For the participants with COVID-19 infection, their parents completed questionnaires approximately three months after the infection, reporting on children's emotion and behavior during the three months preceding infection (pre-COVID) and during the most recent two weeks after infection (post-COVID). The same questionnaires were administered again three years later (follow-up) to evaluate longer-term outcomes. For the healthy controls, their parents completed the same questionnaires once during the COVID-19

pandemic, reporting the child's emotional and behavioral function over the two weeks preceding questionnaire administration.

2.3. Measurements

The measurements included the Social Adjustment Inventory for Children and Adolescents (SAICA) to assess social adjustment and function, the Strengths and Difficulties Questionnaire (SDQ) to evaluate broad emotional and behavioral difficulties as well as strengths, and the Coronavirus Health and Impact Survey (CRISIS) to assess mood-related experiences specifically in the context of the COVID-19 pandemic-related stressors.

2.3.1. Social Adjustment Inventory for Children and Adolescents (SAICA)

The SAICA, consisting of 77 items, is designed to measure the social adjustment of children and adolescents. In the present study, three domains were examined, including school functions, peer relationships, and home behaviors on a four-point Likert scale reported by parents. Although the SAICA was originally developed as a semi-structured interview, the Chinese version has also been administered as a parent-reported questionnaire in previous Taiwanese studies to assess children's real-world social adjustment across school, peer, and home domains^{15,16}. School Functioning assesses academic performance and behavior in the school environment. Peer Relationships assess social interactions and relationships with peers. Home Behavior assesses functioning and relationships within the family environment. Representative items include difficulties completing schoolwork (school functioning), getting along with peers (peer

relationships), and conflicts with family members (home Behavior). The higher scores indicate greater difficulties in social adjustment¹⁷. The Chinese version of the SAICA has demonstrated acceptable reliability and validity in Taiwanese children, with test-retest reliability ranging from 0.45 to 0.84 and internal consistency ranging from 0.71 to 0.86¹⁸. In the present study, the SAICA subscales also showed good internal consistency, with Cronbach's α ranging from 0.87 to 0.90 and McDonald's ω ranging from 0.88 to 0.90 (Supplementary Table S1). The SAICA was included to assess functional impairment and social adjustment in everyday life, which may not be fully captured by symptom-based measures.

2.3.2. Strengths and Difficulties Questionnaire (SDQ)

The SDQ, consisting of 26 items, is a widely used instrument designed to assess emotion and behavior of children and adolescents across four domains, including internalizing symptoms, prosocial behavior, hyperactivity, and conduct problems on a three-point Likert scale ranging from 0 to 2. Representative items include "Often unhappy, depressed or tearful" (Internalizing), "Restless, overactive, cannot stay still for long" (Hyperactivity). The higher scores indicate more difficulties, except for the prosocial domain, where higher scores indicate more adaptive functioning¹⁹. The Chinese version of the SDQ has demonstrated satisfactory reliability and validity among Taiwanese children and adolescents, including a factor structure consistent with the original instrument, as well as good test-retest reliability, concurrent validity, and discriminative validity²⁰. In the current

sample, the SDQ subscales demonstrated acceptable to good internal consistency, with Cronbach's α values ranging from 0.68 to 0.81 and McDonald's ω values ranging from 0.70 to 0.82 (Supplementary Table S1).

2.3.3. The Coronavirus Health and Impact Survey (CRISIS)

The CRISIS is a questionnaire developed to evaluate health status and mental distress during the COVID-19 pandemic and has been used to monitor mental health and related outcomes across different stages of pandemic and into the post-pandemic period. The CRISIS has demonstrated good feasibility, stable psychometric structure, and construct validity across large population samples in the US and UK²¹. In the present study, only the Mood States subscale was used to evaluate emotional symptoms on a five-point Likert scale ranging from 1 to 5. Representative items include "How happy vs. sad was your child?", "How fatigued or tired was your child?" Higher scores on the Enjoy Activities and Happy vs. Sad items indicate greater enjoyment and happiness, whereas higher scores on the remaining CRISIS subscales indicate greater difficulties. The Mood States scale demonstrated good internal consistency in the present sample (Cronbach's $\alpha = 0.839$, McDonald's $\omega = 0.857$, Supplementary Table S1). To capture both overall mood disturbance and specific symptom following COVID-19 infection, analyses were conducted using both the CRISIS Mood States composite score and individual Mood States items.

2.4. Data analyses

Data analyses were performed using IBM SPSS Statistics version 29.0 (IBM

Corp., Armonk, NY, USA). Descriptive statistics were calculated for demographics, emotional, and behavioral performance. Continuous variables were reported as mean and standard deviation (SD), whereas categorical variables were presented as frequency and percentage. The normality of continuous variables was assessed using the Shapiro-Wilk test and visual inspection of Q-Q plots. Linear multilevel models (LMM) were conducted to compare social adjustment, emotional and behavioral problems, and mood-related outcomes between the COVID group and the control group. The comparison included the pre-COVID, post-COVID, and 3-year follow-up conditions of the COVID group and a single assessment of the control group. To account for within-subject correlations arising from repeated measures, participant-level variability was treated as a random effect. Although some variables showed deviations from normality, linear multilevel models are robust to moderate violations of normality assumptions. All analyses controlled for age and sex, and Bonferroni correction was applied to post hoc comparisons within the linear multilevel models. When a significant sex effect was identified in the primary LMM analysis, separate LMM analyses were subsequently conducted for males and females to further characterize sex-specific trajectories. To account for multiple comparisons across outcome measures, p-values were adjusted using the Benjamini-Hochberg false discovery rate (BH-FDR) procedure. Additionally, Correlation analyses were conducted to examine whether the interval between COVID-19 infection and assessments (post-COVID and

follow-up) was associated with emotional and behavioral symptom severity at the corresponding assessment time point.

3. Results

3.1. Sample description

The final analytic sample consisted of 69 children with COVID-19 infection (first year: mean age = 9.59 ± 2.39 ; 43 males, 62.32%; follow-up: mean age = 12.17 ± 2.39 ; 43 males, 62.32%) and 94 healthy controls (mean age = 9.09 ± 2.15 ; 44 males, 46.81%) participated in this study. Table 1 presented the demographics with no significant differences observed in age or sex between the two groups.

Table 1

Demographics of the COVID group at the time points of enrollment and at follow-up, and the control group.

Variable	Control (N=94)	COVID (N=69)	COVID follow-up (N=69)	Test statistic	P value
Age					
mean $\pm$ SD	9.09 $\pm$ 2.15	9.59 $\pm$ 2.39	12.17 $\pm$ 2.39	t = 1.43	0.156
Range	4-14	6-16	8-18		
Sex, n(%)				$\chi^2 = 3.85$	0.05
Male	44 (46.81)	43 (62.32)	43 (62.32)		
Female	50 (53.19)	26 (37.68)	26 (37.68)		

Note: Data are presented as mean $\pm$ SD or n (%).

3.2. Social adjustment problem (SAICA)

Compared with the pre-COVID condition and the control group, the post-COVID condition showed significantly greater impairment in school functioning. Nevertheless, at the three-year follow-up, school functioning no longer differed significantly from the pre-COVID condition, indicating a return to the pre-COVID level, as shown in Table 2.

Table 2

Comparisons of social adjustment problems measured by SAICA.

	Control (N=94)	Pre- COVID (N=69)	Post- COVID (N=69)	3-year follow- up (N=69)	F	FDR- adjusted <i>p</i>	Comparisons ^a
School function	1.26 ± 0.03	1.38 ± 0.04	1.44 ± 0.05	1.39 ± 0.06	4.78	0.033*	3 > 2, 1
Peer relationships	1.28 ± 0.02	1.40 ± 0.04	1.42 ± 0.05	1.41 ± 0.05	0.25	0.778	-
Home behaviors	1.21 ± 0.02	1.29 ± 0.04	1.32 ± 0.04	1.28 ± 0.04	1.92	0.230	-

Note: SAICA, Social Adjustment Inventory for Children and Adolescents. FDR-adjusted *p*-values were obtained using the Benjamini-Hochberg procedure. Bonferroni correction was applied to post hoc pairwise comparisons.

**p* < 0.05.

^a : 1, Control group; 2, the Pre-COVID condition of the COVID group; 3, the Post-COVID condition of the COVID group; 4, the 3-year follow-up condition of the COVID group.

3.3. Strengths and difficulties (SDQ)

Compared with the pre-COVID condition, the post-COVID condition showed significantly greater internalizing symptoms and conduct problems. However, at the three-year follow-up, these differences were no longer significant, indicating a return to the pre-COVID level. In contrast, prosocial

behavior among females showed even greater impairment at the follow-up compared with both the pre-COVID condition and the control group, indicating a failure to return to the pre-COVID level, as shown in Table 3 and Supplementary Table S2.

Table 3

Comparisons of emotional and behavioral problems measured by SDQ.

	Control (N=94)	Pre-COVID (N=69)	Post- COVID (N=69)	3-year follow-up (N=69)	F	FDR- adjusted <i>p</i>	Compa risons ^a
Internaliz ing	1.64 ± 0.18	2.05 ± 0.24	2.50 ± 0.27	2.33 ± 0.29	4.63	0.024*	3 > 2
Prosocial	13.36 ± 0.33	12.22 ± 0.38	12.03 ± 0.42	11.01 ± 0.57	2.95	0.077	-
Prosocial (female)	14.55 ± 0.26	12.46 ± 0.52	11.96 ± 0.68	10.24 ± 0.82	8.39	0.010**	1 > 2 > 4 1 > 3
Hyperacti ve	2.62 ± 0.19	3.19 ± 0.12	3.24 ± 0.13	2.85 ± 0.15	2.05	0.136	-
Conduct	0.81 ± 0.14	0.96 ± 0.20	1.29 ± 0.21	1.31 ± 0.21	7.09	0.004**	3 > 2

Note: SDQ, Strengths and Difficulties Questionnaire. FDR-adjusted p-values were obtained using the Benjamini-Hochberg procedure. Bonferroni correction was applied to post hoc pairwise comparisons. ">" denotes a higher mean score. Higher Prosocial scores indicate better functioning, whereas higher scores on the other SDQ subscales indicate greater difficulties.

**p* < 0.05.

***p* < 0.01.

^a : 1, Control group; 2, the Pre-COVID condition of the COVID group; 3, the Post-COVID condition of the COVID group; 4, the 3-year follow-up condition of the COVID group.

3.4. Coronavirus health and impact (CRISIS)

Compared with both the pre-COVID condition and the control group, the

post-COVID condition showed significantly higher Mood States scores, indicating greater overall emotional distress. At the three-year follow-up, Mood States scores no longer differed significantly from the pre-COVID condition, suggesting a return to pre-COVID levels. For the individual item, compared with the pre-COVID condition, the post-COVID condition showed significantly greater severity of irritability and difficulties with focus in the COVID group. The COVID group also demonstrated nominally increased worry and reduced relaxation among males. However, these findings did not survive FDR correction. At the three-year follow-up, irritability and focus were no longer significantly different from the pre-COVID condition, indicating a return to the pre-COVID condition. In contrast, the COVID group showed nominally significant increase in fatigue compared with the control group across all three time points, including pre-COVID condition, post-COVID condition, and follow-up. This finding also did not survive FDR correction, as shown in Table 4 and Supplementary Table S2.

Table 4

Mood state comparisons measured by CRISIS.

	Control (N=94)	Pre- COVID (N=69)	Post- COVID (N=69)	3-year follow- up (N=69)	F	FDR- adjusted <i>p</i>	Comparisons ^a
Worry	1.58 ± 0.07	1.78 ± 0.11	2.04 ± 0.12	1.93 ± 0.12	2.53	0.135	-
Worry (male)	1.44 ± 0.11	1.65 ± 0.13	2.07 ± 0.15	1.80 ± 0.15	3.94	0.087	3 > 2, 1
Enjoy activities	2.92 ± 0.17	2.92 ± 0.14	2.74 ± 0.13	3.06 ± 0.15	2.13	0.172	-

Fidget	1.36 ± 0.07	1.47 ± 0.09	1.61 ± 0.10	1.51 ± 0.11	0.98	0.416	-
Fatigue	1.29 ± 0.06	1.74 ± 0.10	1.99 ± 0.12	1.91 ± 0.12	3.33	0.110	4, 3, 2 > 1
Irritability	1.51 ± 0.09	1.76 ± 0.11	2.10 ± 0.14	1.96 ± 0.13	6.34	0.017**	4, 3 > 1 3 > 2
Loneliness	1.29 ± 0.07	1.37 ± 0.08	1.40 ± 0.07	1.51 ± 0.11	0.75	0.477	-
Happy vs. Sad	4.25 ± 0.09	3.91 ± 0.10	3.76 ± 0.10	3.88 ± 0.12	3.11	0.110	-
Relaxed vs. Anxious	2.19 ± 0.11	2.53 ± 0.12	2.72 ± 0.13	2.62 ± 0.14	2.55	0.135	-
Relaxed vs. Anxious (male)	2.12 ± 0.16	2.34 ± 0.13	2.59 ± 0.16	2.37 ± 0.18	4.19	0.087	3 > 2
Focus	2.50 ± 0.12	2.58 ± 0.13	2.86 ± 0.13	2.74 ± 0.15	5.37	0.022*	3 > 2
Negative thoughts	2.26 ± 0.08	2.39 ± 0.09	2.49 ± 0.10	2.50 ± 0.13	1.25	0.357	-
Mood States	18.78 ± 0.49	20.72 ± 0.63	22.64 ± 0.74	21.87 ± 0.83	8.02	0.011*	3 > 2, 1 4 > 1

Note: CRISIS, Coronavirus Health and Impact Survey. FDR-adjusted p-values were obtained using the Benjamini-Hochberg procedure. Bonferroni correction was applied to post hoc pairwise comparisons. ">" denotes a higher mean score. Higher scores on the Enjoy Activities and Happy vs. Sad items indicate greater enjoyment and happiness, whereas higher scores on the remaining CRISIS subscales indicate greater difficulties.

* $p < 0.05$.

** $p < 0.01$.

^a : 1, Control group; 2, the Pre-COVID condition of the COVID group; 3, the Post-COVID condition of the COVID group; 4, the 3-year follow-up condition of the COVID group.

3.5. Duration correlation

The interval from COVID-19 infection to the post-COVID assessment was 97.79 ± 90.32 days, whereas the interval to the follow-up assessment was

1024.43 $\pm$ 80.06 days. Correlation analyses showed that a longer interval between infection and the post-COVID assessment was significantly associated with greater enjoyment of activities ($r = 0.29$, $p = 0.020$) and lower levels of fatigue ($r = -0.32$, $p = 0.010$) at the post-COVID assessment. In addition, a longer interval between infection and the follow-up assessment was significantly associated with fewer school function problems ($r = -0.26$, $p = 0.041$) and lower levels of internalizing symptoms ($r = -0.26$, $p = 0.038$) at the follow-up assessment.

4. Discussion

This study investigated the long-term trajectories of social adjustment and emotional/behavioral problems in Taiwanese children following COVID-19 infection. Our results showed that the COVID group exhibited significant impairments in school function, internalizing problems, conduct problems, irritability, and focus in the post-COVID condition compared with the pre-COVID condition. At the three-year follow-up, these impairments were no longer significantly different from the pre-COVID condition. In contrast, prosocial behavior among females failed to recover to the pre-COVID levels. The COVID group also showed a trend toward greater fatigue compared with the control group across all time points, although this difference did not remain significant after FDR correction. A longer interval between infection and the follow-up survey was associated with greater improvement in school function and internalizing symptoms.

Previous studies have shown that PASC, also known as long COVID,

typically emerges after acute COVID-19 infection and tends to remit within several months in a substantial proportion of affected individuals ²².

However, approximately 7.1% of children continue to experience persistent long COVID symptoms up to two years after infection ³. Extending prior findings, the present study demonstrates that following COVID-19 infection, significant impairments in school function, internalizing problems, conduct problems, focus difficulties, and irritability returned to pre-COVID levels by the three-years follow-up. Several studies have suggested that post-COVID sequelae are associated with neurobiological mechanisms related to viral infection, including neuroinflammation and disruption of the blood-brain barrier ²³, as well as psychosocial stress experienced during the pandemic period ²⁴. Based on our three-year follow-up results, psychological impairments related to COVID-19 appear to gradually recover over time in the majority of children. Nevertheless, because long COVID develops in only a minority of children following SARS-CoV-2 infection, the present findings should not be interpreted as representing the general pediatric post-COVID population. Some of the observed difficulties may reflect not only biological effects of COVID-19, but also infection-related distress, family stress, school disruption, social isolation, and other pandemic-related psychosocial challenges.

Although prior studies examining the trajectory of long COVID in children and adolescents have reported heterogeneous results, the overall evidence suggests a gradual improvement in symptoms over time ²⁵. A study revealed

that children with COVID-19 had higher health risks, with 6% experiencing persistent symptoms, although the majority recovered within 12 months ²⁶. Another study reported no increased risks of mood or anxiety disorders in children and adolescents, and observed that cognitive deficits appeared to be transient in nature ²⁷. Besides, long COVID symptoms in children and adolescents demonstrated a steady decline within 6-9 months after infection ²⁸, suggesting a generally favorable trajectory of recovery.

Furthermore, exploratory sex-stratified analyses suggested that prosocial behavior among females not only failed to return to pre-COVID levels but exhibited a further significant decline at the three-year follow-up, suggesting a more persistent and potentially long-lasting adverse impact of COVID-19 on prosocial function in girls. These findings should be interpreted cautiously, as the analyses were exploratory and based on a relatively small sample. Nevertheless, this pattern may reflect heightened sensitivity to social interactions among girls ^{29,30}, whereby behavioral patterns or coping strategies established during periods of social disruption (e.g., school closures, quarantine, and remote learning) persist even after environmental restrictions have been lifted ³¹. This sex difference may also partially reflect greater parental expectations for prosocial behavior and social appropriateness in daughters compared with sons ³². Although fatigue scores were nominally higher in the COVID group than in the control group across all three time points, this difference did not remain significant after FDR correction. Nevertheless, the observed pattern may

indicate that children in the COVID group had elevated fatigue levels even prior to infection. Therefore, the findings should be interpreted cautiously and may reflect pre-existing vulnerability factors rather than a specific consequence of COVID-19 infection. A longitudinal study showed that children and young people with fatigue prior to the pandemic had higher levels of fatigue at follow-up compared with their counterparts, and persistent fatigue remained prevalent for up to 24 months post-infection. Notably, the prevalence of fatigue was already 21.5% among adolescents prior to the pandemic, suggesting that pre-existing fatigue may be misattributed to post-COVID sequelae in some cases ^{33,34}. Additionally, previous studies have found that PASC occurred more frequently among individuals with pre-existing sleep problems and fatigue ^{35,36}. Symptom severity during the early convalescent stage (post-COVID) has been identified as the strongest predictor of fatigue severity at 6 months, while psychological, behavioral, and environmental factors also contributed significantly to the persistence of fatigue among adolescents and young adults ³⁷.

Correlation analyses showed that a longer interval since infection was associated with greater enjoyment of activities, lower levels of fatigue, fewer school function problems, and fewer internalizing symptoms. These findings suggested a gradual recovery trajectory in emotional and behavioral problems among children and adolescents following COVID-19 infection. However, previous studies have reported varying patterns of

recovery trajectories among children and adolescents following COVID-19 infection. A longitudinal study has shown a modest but statistically significant increase in the SDQ score (0.11 per month, 95% CI: 0.09 to 0.12), indicating a gradual decline in mental health among children and young people ³⁸. Another study reported that over 60% of adolescents in China demonstrated favorable mental health trajectories following COVID-19 infection. However, approximately 30% exhibited adverse trajectories, including chronic dysfunction (12.5%), delayed post-pandemic deterioration (10%), and persistent stress-related symptoms with poor recovery (7%) ³⁹. Taken together, these findings underscore the heterogeneity of post-COVID mental health outcomes and highlight the need for further research to delineate the long-term recovery trajectories of long COVID in children and adolescents.

Limitation

There were several limitations in this study. First, the relatively modest sample size and single-center recruitment may limit the generalizability of the findings to broader pediatric populations, and replication in larger, multi-center cohorts will be important to confirm the robustness of these observations. In addition, socioeconomic status was not assessed in the present study, limiting our ability to examine or adjust for the potential influence of family socioeconomic background on post-COVID neuropsychiatric and psychosocial outcomes. The relatively homogeneous ethnic background of the study population may further limit the

generalizability of the findings to more diverse population. Second, pre-COVID emotional and behavioral manifestations were assessed retrospectively using parent-reported measures, which might introduce potential recall bias, as parental perceptions during the post-infection period could influence retrospective reporting. Third, all outcome measures relied on parental reports without additional information, which might introduce potential informant-related bias. Fourth, although an age- and sex-matched control group was included, controls were assessed at a single time point during the pandemic, whereas the COVID group was assessed across pre-COVID, post-COVID, and three-year follow-up conditions. This difference in assessment structure might limit direct comparisons of temporal trajectories between groups. However, the within-subject longitudinal design provided valuable insight into long-term recovery patterns following pediatric COVID-19 infection. In addition, children with COVID-19 who did not develop persistent symptoms were not included as a comparison group, limiting our ability to distinguish long COVID-specific effects from broader consequences of SARS-CoV-2 infection and pandemic-related psychosocial experiences.

Conclusion

This longitudinal study delineated the post-acute trajectories of social adjustment and emotional/behavioral problems in children following COVID-19 infection. The findings indicated that children initially experienced significant impairments in school function, internalizing symptoms, conduct

problems, irritability, and focus in the post-COVID condition. The majority of these symptoms returned to pre-COVID levels by the three-year follow-up, suggesting substantial recovery over time. Greater improvements in activities enjoyment, fatigue, school function, and internalizing symptoms were associated with longer duration since infection. However, prosocial behavior among females showed a persistent decline, failing to recover to baseline levels. In addition, the COVID group showed nominally elevated fatigue across all time points including pre-infection, which may reflect underlying factors that were present prior to COVID-19 infection. These findings highlight the heterogeneity of recovery trajectories and underscore the necessity of ongoing monitoring and sustained awareness to support the long-term social adjustment and mental health of children during the recovery period.

Abbreviations

COVID-19: Coronavirus disease 2019

CNS: Central nervous system

CRISIS: The Coronavirus Health and Impact Survey

LMM: Linear multilevel models

PASC: Post-acute sequelae of COVID

PCC: Post-COVID-19 condition

SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2

SAICA: Social Adjustment Inventory for Children and Adolescents

SDQ: Strengths and Difficulties Questionnaire

Data availability

The datasets used and analyzed in this study are not publicly available due to ethical restrictions and privacy protections currently but are available from the corresponding author upon reasonable request.

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Author contributions

CYS, LYC, and SSFG designed the study, secured funding, and collected data. YJT and CYS conducted statistical analyses and drafted the initial manuscript. All authors contributed to manuscript revision and approved the final version for submission.

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Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Committee of National Taiwan University Hospital (202206053RINC). Written informed consent was obtained from all participants and their parents prior to the assessments.

All procedures followed the ethical standards for research involving minors.

Additional Information

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