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Increased post-COVID-19 behavioral, emotional, and social problems in Taiwanese children

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ABSTRACT

Background: Coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has remarkably impacted children's mental health. Investigating whether COVID-19-related behavioral changes persist after recovery from the acute phase of infection warrants investigation. The present study aimed to identify children's behavioral/emotional and social adjustment problems after SARS-CoV-2 infection.

Methods: 84 children aged 6–16 received assessments within 6 months after being tested positive for COVID-19. Their parents reported observations about their children 3 months before SARS-CoV-2 infection (pre-COVID condition) and the most recent 2 weeks (post-COVID condition) on a wide range of psychopathologies and social functional impairments. A control group consisted of 84 age-, sex-, and IQ-matched healthy children, with the same measures as those employed in the COVID group.

Results: Compared with the control group, the COVID group in the post-COVID condition had more severe symptoms of inattention, hyperactivity-impulsivity, opposition, a wide range of emotional and behavioral problems, and poor school functions, school attitude, social interaction, school behavioral problems, and interaction problems with their parents. Compared with the pre-COVID condition, the COVID group had greater severity of inattention, somatic complaints, thought problems, internalizing problems, poor school functions, and interaction problems with their parents in the post-COVID condition.

Conclusions: The present study identified a significant link between SARS-CoV-2 infection and various post-COVID mental health sequelae in children, including behavioral/emotional and social adjustment challenges. Our results underline the importance of raising awareness about ongoing post-COVID mental health concerns in children.

1. Introduction

The coronavirus disease 2019 (COVID-19) is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Recent studies have found persistent symptoms even after recovery from acute SARS-CoV-2 infection, causing adverse effects on the health outcomes of patients [1]. For example, a retrospective cohort study found that one-third of adults with SARS-CoV-2 infection had neuropsychiatric problems six months after the acute phase [2]. While post-COVID symptoms have mainly been documented in adults [3], there have

been limited studies on long COVID-19 in pediatric patients [4]. Nevertheless, a growing global concern has emerged about the persistent symptoms in children following acute infection. Several studies have revealed significant associations of SARS-CoV-2 infection with multiple physical and neuropsychiatric outcomes during the post-acute phase in children, including respiratory symptoms, nasal congestion, emotional problems, sleep disturbance, inattention, dizziness, headache, and loss of appetite [5]. Among these manifestations, mental health problems were particularly prevalent in post-COVID children, occurring independently or in combination [5].

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The post-COVID sequelae have been observed in severely symptomatic, paucisymptomatic, or asymptomatic children, suggesting that they might develop in any patient with SARS-CoV-2 infection, regardless of the illness severity of the acute phase [6]. Despite high variations among studies, the average prevalence rate of post-COVID sequelae was 25% in children [7]. While the prognosis of post-COVID sequelae is relatively good in most children, a significantly negative impact on daily life may be caused by persistent symptoms in some cases [8]. For example, a recent observational study has shown that 23% of children with long COVID syndrome reported moderate to severe impairment in the quality of life [9].

Several recent studies have reported the impact of COVID-19 infection on the health of children in Taiwan. For example, severe neurological outcomes of hospitalized children were associated with some specific factors, including fatigue, hypoglycemia, behavior change, visual hallucination, myoclonic jerk, and seizure at admission [10]. Children with post-acute sequelae of SARS-CoV-2 infection persisting for more than four weeks experienced fatigue, respiratory illness, changes in appetite and body weight, attentional problems, and lack of motivation [11]. Children without post COVID-19 condition (PCC) had a significant reduction in emotional and behavioral problems during 2-month follow-up, whereas those with PCC had no such improvement [12].

There is still limited information on the post-COVID mental health problems in children. In addition, more studies are needed to differentiate the post-COVID sequelae from the symptoms caused by maladaptive responses to the pandemic [4]. Hence, the present study aimed to investigate children's behavioral, emotional, and social adjustment issues within 6 months following SARS-CoV-2 infection. Compared with healthy controls and the pre-COVID condition, we hypothesized that children who tested positive for SARS-CoV-2 would be at a higher risk of experiencing behavioral, emotional, and social adjustment problems during the first 6 months following infection.

2. Methods

2.1. Participants

This study enrolled 84 children aged 6–16 with SARS-CoV-2 infection, who were defined as being positive with a rapid antigen test kit and confirmed by a medical professional. All patients underwent clinical assessments 1–6 months after testing positive for COVID-19 (mean duration, 163 ± 55 days) at National Taiwan University Children's Hospital from October 6, 2022, to April 30, 2023. In addition, we established a control group matched by age-, sex-, and IQ, consisting of non-infected healthy children who were not infected with SARS-CoV-2 and did not experience the COVID-19 pandemic. Thus, 80 historical controls were identified before April 2022, when the outbreak of the COVID-19 pandemic began with the spread of Omicron variants in Taiwan [13]. Moreover, 4 controls without SARS-CoV-2 infection, confirmed by parental reports, were enrolled after April 2022. All the participants in the present study met the following criteria: (1) full-scale IQ, estimated by Wechsler Intelligence Scale for Children – Fifth Edition (WISC-V), >80 , (2) no current or past history of any major psychiatric disorder confirmed by using the Kiddie epidemiologic version of the Schedule for Affective Disorders and Schizophrenia (K-SADS-E) for DSM-5 [14] interview, such as autism spectrum disorder, schizophrenia, or mood disorders, and (3) no current or past history of any major systemic disease or neurological disorder.

2.2. Procedure

Before implementation, the present study was approved by the Research Ethics Committee of National Taiwan University Hospital, Taiwan (ID, 202206053RINC). The written informed consent was obtained from all the participants and their parents. For the COVID-19-

infected participants, their parents completed the first set of questionnaires about the participants' behaviors in the past three months before being infected by SARS-CoV-2, followed by reporting their observations about the participants in the most recent 2-week after being infected with COVID-19. We had already collected the parent-reported data for the healthy controls before the COVID-19 pandemic, corresponding to those questionnaires employed in the COVID group.

2.3. Measurements

The measurement tools included the K-SADS-E for the diagnosis of psychiatric disorders, the Chinese version of the Swanson, Nolan, and Pelham, version IV scale (SNAP-IV) for ADHD-related symptoms, the Child Behavior Checklist (CBCL) for a wide range of behavioral/emotional problems, and Social Adjustment Inventory for Children and Adolescents (SAICA) for social adjustment.

2.3.1. K-SADS-E

The K-SADS-E was an investigator-rated semi-structured interview scale with good validity and reliability [15]. The parents of all participants were interviewed with the Chinese K-SADS-E to make the diagnoses of DSM-5 psychiatric disorders [16]. The K-SADS-E has been extensively used in previous studies [17–22].

2.3.2. SNAP-IV

The SNAP-IV, a 26-item scale, was designed to measure symptoms of inattention (Item 1–9), hyperactivity/impulsivity (Item 10–18), and opposition (Item 19–26) [23]. The parents of the participants rated each item for the symptom severity of their children on a four-point Likert scale, ranging from 0 (not at all) to 3 (very much). The Chinese version of SNAP-IV demonstrated satisfactory validity and reliability [24], and has been widely employed in clinical studies on ADHD [25].

2.3.3. CBCL

The CBCL was a parent-rated questionnaire designed to assess a broad range of behavioral and emotional problems in children and adolescents. The parents of the participants rated each item for their children's behavioral and emotional problems on a three-point Likert scale, ranging from 0 (not true) to 2 (very true or often true). The CBCL consisted of eight narrow-band syndromes, including aggressive behavior, anxious/depressed symptoms, attention problems, delinquent behavior, social problems, somatic complaints, thought problems, and withdrawn symptoms. In addition, two broad-band dimensions were created, including internalizing (the sum score of anxious/depressed symptoms, withdrawn symptoms, and somatic complaints) and Externalizing (the sum score of delinquent behavior and aggressive behavior) problems. The Chinese version of CBCL has been widely employed to assess behavioral and emotional problems in pediatric populations (e.g., Ref. [26]).

2.3.4. SAICA

The SAICA was designed to assess the social adjustment of children and adolescents, such as school functions, peer relationships, and home behaviors [27]. The parents of the participants rated each item for the social adjustment of their children on a four-point Likert scale. The higher scores indicated greater severity of social adjustment problems. The Chinese version of SAICA had good psychometric properties [28], and has been widely employed in studies on the social adjustment of children and adolescents [29].

2.4. Data analyses

Statistical analyses were conducted using SAS 9.4 (SAS Institute Inc, Cary NC, USA). The continuous variables were displayed as mean and standard deviation (SD), and the categorical variables were frequency and percentage. The three comparison groups were the pre-COVID and

post-COVID conditions of patients with SARS-CoV-2 infection (Pre-COVID and Post-COVID groups, respectively) and control group. To control for the lack of independence between the pre-COVID condition and the post-COVID condition within the same participants, we used a linear multilevel model to compare the ADHD-related symptoms, behavioral/emotional problems, and social adjustment problems treating the same patients with COVID as a random effect. The Bonferroni correction method was applied to adjust for multiple comparisons in post hoc analyses. Additionally, we conducted subgroup analyses, stratified by sex, to compare the post-COVID condition with the control group.

3. Results

3.1. Sample description

Table 1 presented the demographics for participants with COVID-19 infection (age, 10.31 ± 2.55 years; 50 males, 59.52%) and controls (age, 10.14 ± 2.72 years; 50 males, 59.52%). There was no statistically significant difference in age, sex, and FIQ between the two groups. Of 84 participants infected with COVID-19, 14 (16.7%) were diagnosed with ADHD based on K-SADS-E interview with their parents, and 3 had received medications for ADHD. There were 4 participants with multi-system inflammatory syndrome in children (MIS-C).

3.2. ADHD-related symptoms measured by SNAP-IV (Table 2)

Compared to controls, the pre-COVID group had greater severity of opposition symptoms, and the post-COVID group had greater severity of inattention and opposition symptoms. Within the COVID group, we found more severe inattention symptoms in the post-COVID condition than pre-COVID condition Table 2.

3.3. Behavioral/emotional problems measured by CBCL (Table 3)

Compared to controls, the pre-COVID group had more severe aggressive behaviors, anxious/depressed symptoms, attention problems, social problems, somatic complaints, internalizing problems, and externalizing problems, and the post-COVID condition had higher severity of all the eight narrow-band syndromes and two broad-band dimensions of CBCL. Within the COVID group, participants showed more severe somatic complaints, thought problems, and internalizing problems in the post-COVID condition than in the pre-COVID condition Table 3.

3.4. Social adjustment measured by SAICA (Table 4)

Compared to controls, the COVID group showed more severe problems in overall school functions, school attitude, and social interaction, regardless of pre- or post-COVID condition, and school behavioral problems, and less active interactions with parents in the post-COVID condition. Within the COVID group, participants had more severe overall school dysfunctions and less active interactions with parents in the post-COVID condition than in the pre-COVID condition Table 4.

Table 1
Demographics of the COVID and control groups.

Mean \pm SD or N (%)	COVID group (N = 84)	Control group (N = 84)	F statistics	p value
Age	10.31 ± 2.55	10.14 ± 2.72	0.16	0.691
Range	6.1–16.5	6.0–16.9		
Sex				
Male	50 (59.52)	50 (59.52)		
Female	34 (40.48)	34 (40.48)		
Full scale IQ	103.78 ± 14.06	104.46 ± 11.43	0.12	0.732

3.5. Subgroup analyses by sex (Table 5)

Females in the post-COVID condition had more severe SNAP-IV inattention and opposition symptoms and all CBCL subscores, as well as poorer overall school functions, academic performance, school attitude, social interactions, school behavioral problems, peer relationships, and home behaviors than female controls. Males in the post-COVID condition had more severe attention problems, somatic complaints, thought problems, internalizing problems, poorer school attitudes, and social interactions than male controls Table 5.

4. Discussion

As one of few studies, first in Asia, investigating the wide range of clinical and social aspects of children and adolescents infected with COVID-19, we have the following main findings. First, children who had ever been infected by SARS-CoV-2 had more ADHD-related symptoms, more behavioral/emotional problems, and poor social adjustment after recovery from acute infection compared with an age- and sex-matched control group. Second, results from post-COVID-pre-COVID comparisons indicate COVID-19 infection may lead to inattention, somatic complaints, thought problems, internalizing problems, poor school functions, and fewer interactions with parents.

4.1. Pre- and Post-COVID comparisons

Although improvement in certain domains of child's mental health during the COVID-19 pandemic has been reported due to the relief of social and school stress [30], a majority of studies showed the negative effects of the pandemic on the general pediatric population [31]. The present study extended these earlier findings to demonstrate that children in the post-COVID condition were at an even higher risk of inattention, somatic complaints, thought problems, internalizing problems, and difficulty in Interaction with parents than in their pre-COVID condition. Several studies have proposed that the manifestations of post-COVID sequelae depended mainly on the pandemic-related psychosocial factors, such as quarantine and lockdown, instead of the long-term effects of virus infection [32]. Our findings based on comparing the post-COVID condition with the pre-COVID condition suggest increased vulnerability to long-term mental health problems in children. Further studies integrating both biological and psychosocial approaches are needed to examine whether the post-COVID sequelae are the direct results of SARS-CoV-2 infection or the consequences of stress associated with the stringent restrictions for COVID-19 pandemic.

The underlying pathophysiological mechanism of the post-COVID behavioral/emotional and social problems in children remains unclear. Given the negative impact on the central nervous system, several theories have been proposed for the post-COVID neuropsychiatric symptoms [33]. First, brain damage directly caused by SARS-CoV-2 may persist and lead to post-COVID mental health problems. Second, the response of neuroinflammation to SARS-CoV-2 infection may have persistent adverse effects on the brain. Third, the post-COVID symptoms may be caused by the SARS-CoV-2 remaining in the neural networks. Further studies are needed to elucidate the pathogenesis of post-COVID behavioral/emotional and social problems in children.

4.2. Increased behavioral and social problems in the COVID group

Our results showed more opposition symptoms, behavioral/emotional problems, and social maladjustment in pre-COVID than controls, and, additionally, 14 subjects in the COVID group had pre-existing ADHD diagnoses, which could be explained as follows. Children with mental health problems were at a higher risk of SARS-CoV-2 infection [34], e.g., an adjusted odds ratio of 1.58 of having SARS-CoV-2 infection in patients with ADHD [34]. These pre-existing mental health problems might interfere with a child's ability to comply with

Table 2

Comparisons of the ADHD symptomatology measured by SNAP-IV.

Mean \pm SD	Control (N = 84)	Pre-COVID condition (N = 84)	Post-COVID condition (N = 84)	F statistics	Comparisons ^a
Inattention	5.51 \pm 4.05	6.75 \pm 5.34	7.65 \pm 5.69	5.89*	1, 2 < 3
Hyperactivity/Impulsivity	3.14 \pm 4.17	4.39 \pm 4.06	4.60 \pm 4.60	2.51	
Opposition	3.92 \pm 3.98	5.64 \pm 4.27	6.05 \pm 5.09	5.03*	1 < 2, 3

Note: ADHD, attention-deficit/hyperactivity disorder; SNAP-IV, Swanson, Nolan, and Pelham, version IV scale.* $p < 0.05$.^a 1, Control group; 2, the Pre-COVID condition of the COVID group; 3, the Post-COVID condition of the COVID group.**Table 3**

Comparisons of the behavioral/emotional problems measured by CBCL.

Mean \pm SD	Control (N = 84)	Pre-COVID condition (N = 84)	Post-COVID condition (N = 84)	F statistics	Comparisons ^a
Aggressive behavior	2.57 \pm 3.39	4.83 \pm 5.60	5.05 \pm 6.18	5.33*	1 < 2, 3
Anxious/Depressed	1.92 \pm 2.93	3.74 \pm 4.97	4.10 \pm 5.38	5.84*	1 < 2, 3
Attention problems	1.90 \pm 2.63	3.49 \pm 3.93	3.93 \pm 3.82	8.04**	1 < 2, 3
Delinquent behavior	0.88 \pm 1.31	1.50 \pm 2.09	1.61 \pm 2.44	3.16*	1 < 3
Social problems	1.27 \pm 1.69	2.27 \pm 2.65	2.29 \pm 2.53	4.47*	1 < 2, 3
Somatic complaints	0.41 \pm 1.08	1.59 \pm 2.51	2.91 \pm 2.86	35.30***	1 < 2 < 3
Thought problems	0.25 \pm 0.92	0.54 \pm 0.84	0.86 \pm 1.35	7.59**	1, 2 < 3
Withdrawn	1.38 \pm 1.94	2.13 \pm 2.44	2.46 \pm 2.74	5.56*	1 < 3
Internalizing problems	3.71 \pm 4.76	7.46 \pm 8.47	9.48 \pm 9.54	18.30***	1 < 2 < 3
Externalizing problems	3.45 \pm 4.38	6.33 \pm 7.20	6.66 \pm 8.23	5.25*	1 < 2, 3

Note: CBCL, Child Behavior Checklist.* $p < 0.05$.** $p < 0.01$.*** $p < 0.001$.^a 1, Control group; 2, the Pre-COVID condition of the COVID group; 3, the Post-COVID condition of the COVID group.**Table 4**

Comparisons of the social adjustment problems measured by SAICA.

Mean \pm SD	Control (N = 84)	Pre-COVID condition (N = 84)	Post-COVID condition (N = 84)	F statistics	Comparisons ^a
Overall school functions	1.24 \pm 0.26	1.38 \pm 0.36	1.44 \pm 0.41	9.08**	1 < 2 < 3
Academic performance	1.47 \pm 0.57	1.57 \pm 0.74	1.67 \pm 0.83	3.41*	–
School attitude	1.41 \pm 0.56	1.70 \pm 0.83	1.83 \pm 0.89	7.14*	1 < 2, 3
Social interaction	1.25 \pm 0.37	1.49 \pm 0.60	1.48 \pm 0.60	4.78*	1 < 2, 3
School behavioral problem	1.13 \pm 0.22	1.24 \pm 0.31	1.28 \pm 0.37	6.50*	1 < 3
Overall peer relationships	1.34 \pm 0.25	1.42 \pm 0.37	1.42 \pm 0.39	1.10	–
Relationship with peers	1.81 \pm 0.54	1.91 \pm 0.67	1.86 \pm 0.67	1.61	–
Problem with peers	1.13 \pm 0.18	1.19 \pm 0.30	1.19 \pm 0.31	1.52	–
Overall home behaviors	1.21 \pm 0.28	1.27 \pm 0.29	1.43 \pm 1.00	2.71	–
Relationship with sibling	1.34 \pm 0.45	1.44 \pm 0.60	2.79 \pm 11.13	1.69	–
Problem with sibling	1.07 \pm 0.23	1.10 \pm 0.25	1.09 \pm 0.21	0.19	–
Interaction with sibling	1.16 \pm 0.26	1.21 \pm 0.30	2.50 \pm 11.15	1.37	–
Relationship with mother	1.24 \pm 0.43	1.30 \pm 0.42	1.39 \pm 0.50	4.02*	–
Relationship with father	1.43 \pm 0.59	1.50 \pm 0.64	1.58 \pm 0.68	2.71	–
Problem with parents	1.11 \pm 0.24	1.18 \pm 0.33	1.23 \pm 0.38	3.41*	–
Interaction with parents	1.25 \pm 0.36	1.31 \pm 0.36	1.38 \pm 0.41	4.59*	1, 2 < 3

Note: SAICA, Social Adjustment Inventory for Children and Adolescents.* $p < 0.05$.** $p < 0.01$.^a 1, Control group; 2, the Pre-COVID condition of the COVID group; 3, the Post-COVID condition of the COVID group.

preventive measures for SARS-CoV-2 infection, such as maintenance of personal hygiene, social distancing, and movement restrictions.

In contrast, the COVID-19 pandemic could increase the risk of mental health problems in the general population, regardless of infection status. For example, a national survey found a significant increase in anxiety and depression symptoms among children during the COVID-19 pandemic [35]. Compared with the pre-pandemic estimates, the pooled prevalence of anxiety and depression has doubled during the pandemic [36]. A meta-analytic review also showed increased externalizing and internalizing problems in children due to the COVID-19 pandemic [37]. In addition, several studies showed increased scores on the CBCL during the COVID-19 pandemic in children with neuropsychiatric disorders, such as epilepsy [38] and tics [39]. The pandemic might have negative effects on the mental health of children through

fears of illness, loss of caregivers, and perceived disruptions to social interactions and daily activities [40].

4.3. Sex difference

Subgroup analyses showed more pronounced behavioral/emotional and social adjustment problems in girls in the COVID group than control girls. Previous studies have shown that girls were more vulnerable to developing post-COVID sequelae [41]. In line with these findings, a meta-analytic review has also found that female gender was one of the risk factors associated with long COVID symptoms in the pediatric population [5]. Although several biological studies have reported sex-based differences in the expression of ACE2 receptors [42] and immune responses to SARS-CoV-2 infection [43], the underlying

Table 5
Subgroup analyses by sex.

Mean (SD)	Post-COVID condition	Control	<i>p</i>	Post-COVID condition	Control	<i>p</i>
	Male (n = 50)			Female (n = 34)		
SNAP-IV						
Inattention	8.14 (5.60)	6.31 (4.06)	–	6.94 (5.84)	4.33 (3.79)	0.033
Hyperactivity/Impulsivity	5.08 (4.90)	3.68 (4.24)	–	3.88 (4.09)	2.35 (3.99)	–
Oppositional	5.82 (5.46)	4.62 (4.54)	–	6.38 (4.56)	2.88 (2.73)	<0.001
CBCL						
Aggressive behavior	5.04 (6.76)	3.12 (3.88)	–	5.06 (5.31)	1.77 (2.35)	0.002
Anxious/Depressed	2.91 (4.33)	1.76 (2.65)	–	5.85 (6.30)	2.15 (3.34)	0.004
Attention problems	3.82 (3.87)	2.25 (2.86)	0.023	4.09 (3.81)	1.38 (2.20)	<0.001
Delinquent behavior	1.76 (2.91)	1.20 (1.51)	–	1.38 (1.52)	0.41 (0.74)	0.001
Social problems	2.22 (2.72)	1.72 (1.96)	–	2.38 (2.27)	0.62 (0.85)	<0.001
Somatic complaints	2.64 (2.80)	0.32 (0.89)	<0.001	3.31 (2.94)	0.56 (1.31)	<0.001
Thought problems	0.72 (1.09)	0.28 (1.09)	0.046	1.06 (1.67)	0.21 (0.59)	0.006
Withdrawn	1.72 (2.20)	1.48 (2.25)	–	3.56 (3.09)	1.24 (1.39)	<0.001
Internalizing problems	7.27 (7.91)	3.56 (4.62)	0.005	12.72 (10.84)	3.94 (5.03)	<0.001
Externalizing problems	6.80 (9.35)	4.32 (5.04)	–	6.44 (6.37)	2.18 (2.77)	<0.001
SAICA						
Overall school functions	1.42 (0.41)	1.28 (0.28)	–	1.47 (0.42)	1.19 (0.21)	<0.001
Academic performance	1.66 (0.84)	1.55 (0.62)	–	1.70 (0.82)	1.36 (0.47)	0.045
School attitude	1.82 (0.90)	1.44 (0.58)	0.013	1.85 (0.89)	1.38 (0.55)	0.011
Social interaction	1.43 (0.50)	1.23 (0.35)	0.028	1.56 (0.72)	1.27 (0.39)	0.047
School behavioral problem	1.26 (0.38)	1.17 (0.25)	–	1.31 (0.36)	1.08 (0.15)	0.001
Overall peer relationships	1.37 (0.33)	1.38 (0.28)	–	1.48 (0.45)	1.29 (0.19)	0.023
Relationship with peers	1.80 (0.65)	1.91 (0.58)	–	1.94 (0.69)	1.67 (0.43)	–
Problem with peers	1.17 (0.27)	1.14 (0.20)	–	1.23 (0.36)	1.11 (0.15)	–
Overall home behaviors	1.30 (0.33)	1.23 (0.32)	–	1.61 (1.52)	1.19 (0.21)	–
Relationship with sibling	1.53 (0.69)	1.39 (0.49)	–	4.57 (17.24)	1.26 (0.38)	–
Problem with sibling	1.07 (0.21)	1.09 (0.27)	–	1.11 (0.21)	1.06 (0.14)	–
Interaction with sibling	1.22 (0.31)	1.19 (0.30)	–	4.31 (17.28)	1.12 (0.17)	–
Relationship with mother	1.37 (0.44)	1.23 (0.45)	–	1.42 (0.59)	1.25 (0.40)	–
Relationship with father	1.54 (0.67)	1.43 (0.59)	–	1.64 (0.72)	1.42 (0.59)	–
Problem with parents	1.22 (0.40)	1.14 (0.30)	–	1.24 (0.34)	1.07 (0.13)	0.009
Interaction with parents	1.36 (0.40)	1.26 (0.40)	–	1.41 (0.42)	1.23 (0.29)	0.042

Note: SNAP-IV, Swanson, Nolan, and Pelham, version IV scale; CBCL, Child Behavior Checklist; SAICA, Social Adjustment Inventory for Children and Adolescents.

pathophysiological mechanisms of female predominance of post-COVID mental health problems in children remain to be elucidated.

4.4. Methodological consideration

While interpreting the findings from the present study, several methodological limitations must be considered. First, although there were historical controls representing the baseline pre-pandemic condition for children uninfected by the SARS-CoV-2, our present study enrolled few contemporary controls, who experienced the same impact of COVID-19 pandemic on mental health without evidence of infection. To facilitate a better understanding of the complex relationships between SARS-CoV-2 infection and mental health problems, further studies are needed to investigate the post-COVID symptoms of children compared with both historical controls predating the pandemic and contemporary controls with no evidence of SARS-CoV-2 infection.

Second, the present study explored the outcomes of behavioral/emotional and social adjustment problems in children 1–6 months after being tested positive for COVID-19. The post-COVID mental health problems of children could persist more than one year after the acute phase of SARS-CoV-2 infection, which might also fluctuate in frequency and severity [5]. Further, longitudinal studies are needed to identify the long-term mental health outcomes in children after SARS-CoV-2 infection.

Third, given that the parents of the COVID group were required to recall children's manifestations of behavioral/emotional and social adjustment problems 3 months before infection by SARS-CoV-2, the present study might introduce recall bias to the findings.

Fourth, antibody testing was not performed to confirm the negative serologic results of SARS-CoV-2 infection in the controls. However, the contamination of controls might be minimal, given that the COVID-19 pandemic did not remarkably strike Taiwan till April 2022, when the

beginning of the outbreak was caused by the spread of Omicron variants of SARS-CoV-2 [13]. Although we were unable to examine whether those controls enrolled after the outbreak of the COVID-19 pandemic in Taiwan had undetected asymptomatic SARS-CoV-2 infection, the results would have been biased towards decreased between-group differences in behavioral/emotional and social adjustment problems by the possible contamination.

Fifth, since the present study was conducted during the period dominated by Omicron variants, our findings may not be generalized to the post-COVID condition of children infected with other variants.

Sixth, the sample size of our present study was relatively small. However, the inclusion of age- and sex-matched controls might mitigate this limitation.

On the other hand, the present study had several strengths. First, the baseline characteristics were comparable between the COVID and control groups. Second, using validated and well-established assessment instruments for children, we measured a wide range of behavioral/emotional and social adjustment problems to detect broad-spectrum symptoms that post-COVID sequelae might present. Third, given that the questionnaires for the COVID group were exactly the same as those for the control group, the comparability between the two groups was enhanced. Fourth, by employing a within-subject comparison design (comparing post-COVID condition to the pre-COVID condition), the present study could differentiate long COVID symptoms from those symptoms associated with maladaptive reactions to the COVID-19 pandemic [4].

In conclusion, this study highlights the potential association between SARS-CoV-2 infection and increased risks of behavioral/emotional problems and impaired social adjustment among children who survive the acute phase. In addition, our findings support the bidirectional connection between SARS-CoV-2 infection and mental health problems [44], implying that behavioral/emotional problems and poor social

adjustment may predispose children to being infected by SARS-CoV-2, and SARS-CoV-2 infection itself may cause mental health problems in children. Our findings underscore the importance of raising awareness about the adverse mental health impacts of SARS-CoV-2 infection in children. Moreover, there is a critical need to integrate the mental healthcare resources to formulate effective strategies for the early identification and intervention in children experiencing post-COVID sequelae.

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Declaration of competing interest

The authors declare no conflict of interest in reporting this study.

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