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Long COVID in children and adolescents: a historical cohort study with a population-based control group from Iran

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Abstract

Background After recovering from the acute phase of COVID-19, some of the infected children manifest long COVID symptoms. The present study aims to identify long COVID symptoms in children and adolescents admitted to hospitals in Bushehr, Iran, during 2021 to 2023, and compare them with the non-affected group.

Methods This historical cohort study with a population-based control group was conducted on 141 children and adolescents with COVID-19 hospitalized in Bushehr city hospitals and 141 non-affected peers. Out of 10 comprehensive health service centers in Bushehr city, 5 centers were selected by random sampling and the non-Covid-19 group was chosen from them (matched by gender and age with the affected group). The data were collected using the data recorded in the patients' records, conducting telephone interviews and completing the prevalent long COVID symptom form. Data were analyzed using SPSS version 18. Descriptive statistics, Chi-square/Fisher's exact tests, and stepwise logistic regression were used. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated, with $p < 0.05$ as the significance level.

Results The mean age of the hospitalized children with COVID-19 was 79 ± 5.24 months old, 57.4% of whom were boys. Also, 46 individuals of the COVID-19 group (32.6%) manifested long COVID symptoms. The most prevalent symptoms included fatigue (54.3%), impaired attention or concentration (41.3%) and depression or anxiety symptoms (34.7%). Among the hospitalized children experiencing long-term COVID symptoms, 65.2% exhibited moderate disease severity. A significant relationship was identified between disease severity and muscle and joint pain ($P = 0.025$), as well as between the length of hospital stay and cough ($P = 0.022$), weight loss ($P = 0.047$), and symptoms of depression or anxiety ($P = 0.008$). Older age [(6–11 y; OR = 3.18, CI = 1.03–9.88); (12 ≥ y; OR = 4.57, CI = 1.40-14.96)] and having history of smoking or being exposed to secondhand smoke (OR = 12.45, CI = 3.14–49.36) were considered as risk factors for long COVID.

Conclusions The variables of age and history of exposure to tobacco smoke exhibited a significant independent relationship with the occurrence of long-term COVID symptoms in children hospitalized due to COVID-19. Specifically,

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as age increases and the history of tobacco smoke exposure rises, the likelihood of experiencing long-term COVID symptoms also increases.

Keywords Adolescents, Children, COVID-19, Complications, Post-COVID-19 syndrome, Iran

Introduction

At the beginning, COVID-19 pandemic affected millions of people worldwide, mostly adults, with fewer cases of children. However, later, studies show the infection rate was also significant among children [1, 2]. Following the emergence of Omicron variant and increasing rate of infection among children, COVID-19 seriously received attention among this age group [3]. Despite the focus of reports on adults and existence of less data on children, studies have demonstrated children experience long COVID as adults [4, 5]. World Health Organization (WHO) defined long COVID as continuation or development of new symptoms for 3 months after the initial SARS-CoV-2 infection, with these symptoms lasting for at least 2 months without any other explanation [6]. The prevalence rate of long COVID varies in different studies and communities. A systematic review study reported this rate as 3.67–66.49% [7, 8]. Long COVID has a multisystem nature and its symptoms could manifest in multiple body systems [9]. Long-term COVID not only causes multi-organ physical issues but also leads to adverse psychiatric effects and toxic stress for those infected [10], It results in a lower quality of life compared to symptom-free individuals [11], and has negative social ramifications, such as decreased labor productivity, heightened national debt, and detrimental effects on children's education [12]. The main causes of long COVID infection are still unknown. This complex syndrome, with a wide range of symptoms, is still evolving [13]. Although numerous studies have been conducted so far, there are limited clinical data on long COVID among children [14]. Few studies have investigated this disease in children, leading to limited information on symptom severity, clinical progression, impact on daily functioning, and recovery to baseline health [15, 16]. Even these reports are contradictory about the prevalence, duration of symptoms and its effect [17]. Moreover, the frequency of persistent post-COVID-19 symptoms is not precisely known among children and adolescents because all studies conducted on this age group have significant limitations [18]; for example, Asadi Pooya et al. (2021) conducted a study in Iran with a limited sample size and no control group, reporting a long-term prevalence rate of 44.8%. Also, in the study carried out by Kikkenborg et al. (2022) in Denmark, despite having large sample size and a control group, the research was limited to the period when alpha and delta variants were dominant [19, 20]. Lopez-Leon et al. (2022) reported that almost all studies on long COVID are likely to be biased, including lack of standard definitions, recall, selection and non-response [21].

Given our current knowledge about the long-term effects of COVID-19 and its biological basis, this disease should be seriously taken. On a global scale, long COVID has not received great attention and there is general lack of public awareness [22]. Moreover, different aspects of this disease are not well understood as it affects COVID-19 survivors at all levels of disease severity, even individuals with different age groups who did not need hospitalization in the acute phase [23]. Therefore, further studies should be conducted to optimally manage these emergency conditions and determine the required resources for long COVID syndrome or lifelong effects of SARS-CoV-2 in children and adolescents [24]. Given the epidemiological nature of this disease and the prevalence of long COVID in various regions, along with the specific conditions in Bushehr—such as the limited number of hospitals dedicated to COVID-19 patients, hot and humid weather, and the potential effects of mask-wearing and respiratory protection— There is not enough research on this issue in children and adolescents, particularly in Iran. This highlights the necessity of conducting more studies to identify the prevalence of long covid symptoms in the population of children and adolescents and its risk factors in order to help in the early detection of long covid symptoms and possibly help in their timely follow-up and treatment. Therefore, this study was conducted to identify long COVID symptoms in children and adolescents hospitalized in Bushehr, Iran, from 2021 to 2023, and to compare these symptoms with those in a non-affected group.

Methods

Study design and participants

This historical cohort study with a population-based control group was conducted on all children and adolescents from birth to the age of 17 years, 11 months and 29 days old who were diagnosed with COVID-19 and hospitalized at Bushehr hospitals from March 21, 2021, to March 20, 2023. This group was considered as the COVID-19-infected group. This study included an equal number of healthy children and adolescents, matched by gender and age with the affected group, who exhibited no Covid-19 symptoms. These participants were selected from five comprehensive health service centers in Bushehr, chosen randomly from a total of ten centers in the city, thereby forming the non-Covid-19 control group. For the non-COVID-19 group samples from each

center, we first created a list of children and adolescents who fell within the eligible age range and the timeframe of March 21, 2021, to March 20, 2023, when COVID-19 patients reported their symptoms. Those receiving care at the Comprehensive Health Services Center were then contacted. Participants who met the entry criteria were consecutively included in the study. For each child and adolescent affected by COVID-19, a healthy child and adolescent was also sampled. Inclusion criteria for the COVID-19 group included being 17 years, 11 months, and 29 days old or younger, hospitalized in Bushehr with COVID-19 symptoms from 2021 to 2023, a positive PCR or rapid test result, and verbal consent from parents and adolescents aged 12 and older. For the non-COVID-19 group, criteria included the same age limit, matching demographic characteristics (gender and three age groups: under 5 years, 5–12 years, and 12–18 years) with the affected group, and verbal consent from parents and adolescents aged 12 and older. Exclusion criteria for the Covid-19 group include the loss of a family member within the last six months or failure to complete a disease profile form by phone. For the non-Covid-19 group, individuals must not have had any risk of contracting the disease (a child's Covid-19 diagnosis was based on symptoms reported by parents or on the child's report of loss of smell or taste, as confirmed by a doctor). The purpose of considering a non-Covid-19 group was to investigate the common symptoms in long-term COVID, as was done with the Covid-19 group. This enhances confidence in attributing any long-term symptoms directly to the disease.

In total, 166 children and adolescents diagnosed with COVID-19 were hospitalized at Bushehr hospitals in 2021–2023. Of these, eight individuals (4.8%) died, 15 cases (9.03%) had negative PCR test result and two individuals (1.2%) were not willing to participate in the study. In total, 141 individuals were included in the study as the COVID-19 group and 141 individuals were included as the non-affected group.

Data collection tool

To prepare the data collection tool, we designed it based on various sources, including the Post-Covid-19 Functional Status Scale Manual, Children Symptom Inventory-4, Post-COVID Health History and Symptom Checklist, Patient Questionnaire for Long Covid, and Long Covid Pre-Assessment Questionnaire, along with expert panel opinions to assess long-term COVID symptoms in children and adolescents [25, 26]. The World Health Organization (WHO) defines long-term COVID as the persistence or emergence of new symptoms for at least 3 months after the initial SARS-CoV-2 infection, which must continue for at least 2 months without an alternative explanation; this definition informed our long-term COVID criteria [6].

The research tool consisted of closed-answer (multiple-choice) and open-answer (explanatory) questions to gather information through two methods: reviewing hospital records of affected individuals and conducting telephone interviews. The data collected included demographic information and a list of 26 common symptoms associated with long-term COVID, including impaired attention, brain fog, headache, dizziness, hair loss, tingling, earache, rhinitis, sore throat, changes in taste or smell, palpitations, chest pain, chest discomfort, cough, shortness of breath, abdominal pain, nausea, diarrhea, weight loss, appetite changes, weakness, joint and muscle pain, symptoms of depression or anxiety, sleep disorders, fatigue, and skin rashes. Initially, participants were asked if their child had experienced any new or persistent symptoms after recovering from the acute phase of Covid-19 and being discharged from the hospital. If so, they were prompted to specify which symptoms they encountered. Each common symptom was then presented, and those experienced by the participant were evaluated further. Questions included whether the symptom was present before contracting Covid, if it worsened afterward, the duration of the symptom post-recovery (in days, months, or years), and its frequency (daily, every few days, or occasionally). Clear examples and scientific definitions were provided for each symptom to enhance participants' comprehension. Individuals who reported experiencing at least one symptom for over three months after recovering from the acute phase of Covid-19 were classified as having long-term Covid-19. The demographic information collected included gender, age, smoking history, hospitalization department, hospitalization and discharge dates, medical records, initial symptoms during hospitalization, lung involvement assessed via CT or HRCT, SPO2 levels, and the patients' need for medical care. This data was gathered through participant files and telephone interviews conducted by the first researcher, a master's student in pediatric nursing familiar with long-term Covid symptoms and interview standards. The severity of the disease during the acute phase was assessed using the 11th version of the COVID-19 diagnosis and treatment flowchart, which categorized the need for medical care into four levels: mild, moderate, severe, and very severe [27]. At the end, general opinions were gathered through four questions: (1) Possible effects of symptoms on life, in a multiple-choice format; (2) Inability or impatience to attend school or sports, as a yes/no question; (3) Evaluation of health status compared to before COVID-19 and hospitalization, using a three-option scale (better/worse/no difference); and (4) Whether or not they visited a doctor for stable symptoms, as a yes/no question. If children were unable to communicate, preferably their mothers

were interviewed. The first researcher contacted all hospitalized individuals who had recovered from the acute phase of COVID-19, explained the study's objectives, obtained verbal consent, and assessed their health status using the long-term COVID symptoms survey form.

Except for the questions about the child's hospitalization, the remaining questions were also directed at unaffected children and adolescents. To address potential difficulties in recalling symptoms, we designed the symptom and disease characteristic questions to be detailed and precise. During interviews, we aimed to gather as much detailed information as possible, providing necessary explanations. If a participant did not answer the phone, they were called three times before being excluded from the study.

Statistical analyses

Data were analyzed using SPSS version 18. Descriptive statistics, including means, standard deviations, and percentages, summarized the data. Chi-square or Fisher's exact tests were used for categorical variables, and independent samples t-test was applied for continuous variables. Variables with a p-value < 0.2 in these tests were included in a forward stepwise logistic regression model (using the forward Wald method) to identify independent predictors of long COVID symptoms. A p-value < 0.05 was considered statistically significant, and odds ratios (ORs) with 95% confidence intervals (CIs) were calculated.

Standard protocol approvals

This research was approved by Ethics Committee of Bushehr University of Medical Sciences with reference no. IR.BPUMS.REC.1402.038. Verbal consent was obtained from parents and adolescents.

Results

General characteristic of the participants

There were 60 girls (42.6%) and 81 boys (57.4%) per group. The mean (±standard deviation) of age for both the COVID-19 group and non-COVID-19-affected group groups were 79.16±5.24 and 79.13±5.23 months old, respectively (t = 0.004, $p = 0.99$). According to the chi-square test, there was a significant difference between the two groups in demographic variables of ethnicity ($p = 0.001$), relationship with the child (respondent) ($p = 0.015$), exposure to tobacco smoke (p = < 0.001), underlying diseases of asthma($p = 0.030$), seizures ($p = 0.030$) and other medical records (p = < 0.001) (Table 1). The logistic regression results showed that in individuals with a history of hospitalization due to COVID-19, the likelihood of hospitalization for non-Bushehri Persons was 3.86 times that of Bushehri Persons. Similarly, in individuals with COVID-19 hospitalization, the likelihood of having other medical histories was 4.6 times higher than that of the non-COVID-19-affected group. Controlling for the effects of significant factors indicated that factors such as history of smoking or being exposed to secondhand smoke and ethnicity had an independent relationship with the occurrence of COVID-19 and hospitalization.

Clinical characteristics of the patients with covid-19

The most prevalent symptoms of patients in the COVID-19 group during hospitalization included fever (72.3%), cough (37.6%), vomiting (23.4%), diarrhea (17%) and shortness of breath (12.8%). The mean (±SD) length of hospital stay for this group was 4.90±2.72, ranging from 2 to 21 days.

Long COVID manifestations

Out of 141 individuals with COVID-19, 95 individuals (67.4%) reported no persistent symptoms. Forty-six individuals (32.6%) in the COVID-19 group had at least one symptom of long COVID symptoms. In the non-affected group, only one case complained of persistent nasal congestion for a month and, in general, no one reported long COVID symptoms. The most prevalent long COVID symptoms included fatigue (54.3%), impaired attention or concentration (41.3%), depression or anxiety (34.7%) and hair loss (32.6%), respectively (Fig. 1).

Impact of long covid symptoms on children and adolescents

Out of the 46 children and adolescents who complained of manifestations or persistence of long COVID symptoms, 17.4% reported difficulties with good quality of life and studying, 15.2% with going to school and participating in group activities, 10.9% with self-care, and 6.5% with daily life activities, being active, and doing sports.

Severity of acute covid-19 and its impact on long covid symptoms

In the acute phase of COVID-19, at the time of hospitalization, the severity of the disease among individuals who later experienced Long COVID symptoms was as follows: 8 individuals (17.3%) had mild disease, 13 individuals (65.4%) had moderate disease, 8 individuals (17.3%) had severe disease. Out of 46 individuals who were hospitalized and later experienced Long COVID symptoms, only 19 (41.3%) after discharging from hospital, sought medical attention for these persistent symptoms. The remaining 27 individuals (58.7%) did not seek medical attention for their ongoing symptoms. Additionally, the Chi-square test revealed a significant relationship between the severity of the acute phase disease and the persistence of muscle and joint pain symptoms ($P = 0.025$).

Table 1 Comparison of demographic variables between COVID-19 patients and control group

Variable		The group affected by COVID-19 (*N* = 141) Number (percentage)	Non-COVID-19 affected group (*N* = 141) Number (percentage)	χ^2	*P*-value
Sex	Female	60(42.6)	60(42.6)	0.001	1.000
	Male	81(57.4)	81(57.4)		
Respondent's relation to the child	Parent or legal guardian	127(90.1)	137(97.2)	5.934	0.015¶
	Individual	14(9.9)	4(2.8)		
Ethnicity	Fars	117(82.9)	134(95)	17.941	0.001*¶¶
	Lor	4(2.8)	1(0.7)		
	Turk	4(2.8)	1(0.7)		
	Kurd	1(0.7)	0(0)		
	Foreign nationals	4(2.8)	5(3.6)		
	Other ethnicities	11(8)	0(0)		
History of tobacco use	Yes	1(0.7)	1(0.7)	18.613	< 0.0001*¶¶¶
	No	125(88.7)	140(99.3)		
	Exposure to tobacco smoke	15(10.6)	0(0)		
Receiving the COVID-19 vaccine	Yes	20(14.2)	20(14.2)	> 0.0001	1.000
	No	121(85.8)	121(85.8)		
History of diabetes	Yes	2(1.4)	0(0)	-	0.498*
	No	139(98.6)	141(100)		
History of cardiovascular disorders	Yes	3(2.1)	0(0)	-	0.247*
	No	138(97.9)	141(100)		
History of metabolic disorders	Yes	3(2.1)	0(0)	-	0.247*
	No	138(97.9)	141(100)		
History of autoimmune disorders	Yes	1(0.7)	0(0)	-	1.000*
	No	140(99.3)	141(100)		
History of asthma	Yes	6(4.3)	0(0)	-	0.030*¶
	No	135(95.7)	141(100)		
History of seizures	Yes	6(4.3)	0(0)	-	0.030*¶
	No	135(95.7)	141(100)		
Other medical history	Yes	25(17.7)	3(2.1)	189.281	> 0.0001¶¶¶
	No	116(82.3)	138(97.9)		

* Fischer's Exact test

¶Significance $P \leq 0.05$

¶¶Significance $P \leq 0.001$

¶¶¶Significance $P \leq 0.0001$

Symptoms of long-term covid according to different age groups of children

Differences in Long COVID symptoms were observed across various age groups of children. A significant relationship was found between the symptoms of abdominal pain ($p=0.002$) and diarrhea ($p=0.001$) and age group. Diarrhea was more prevalent in children under 2 years old (42.8%), while abdominal pain was more prevalent in children aged 2 to 5 years (57.2%). No significant differences were found in other symptoms among children of different age groups (Table 2).

Hospitalization duration and the prevalence of long-term COVID symptoms

We identified a significant relationship between the length of hospitalization and the occurrence of specific long-term COVID symptoms, including cough ($p=0.022$), weight loss ($p=0.047$), and symptoms of depression or anxiety ($p=0.008$). Longer hospital stays increase the likelihood of these symptoms affecting more patients.

Risk factors associated with long-term covid

Regarding potential risk factors for Long COVID, as shown in Table 3, although 19.6% of individuals with Long COVID, compared to 12.6% of those without long COVID, had a history of hospitalization in neonatal or pediatric intensive care units (NICU/PICU), there was no significant relationship between NICU/PICU admission and the occurrence of Long COVID symptoms. Similarly, no significant relationship was found between gender, ethnicity and multiple ward admission and the

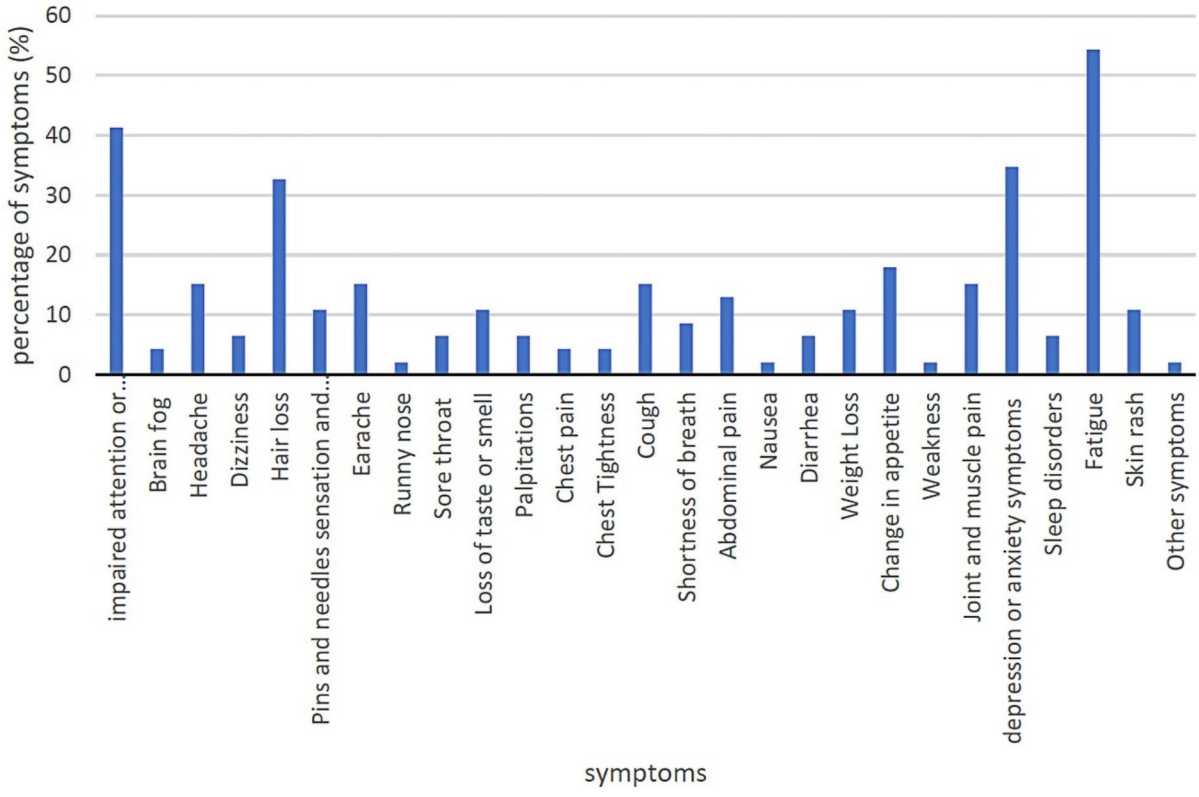

Fig. 1 Prevalence of long Covid symptoms in children and adolescents by percentage

manifestation of Long COVID symptoms in children and adolescents infected with COVID-19 ($p > 0.05$).

In the univariate analysis, variables with p-values less than 0.2 were included in the forward stepwise multivariate logistic regression with Wald statistics. These variables were history of exposure to tobacco smoke ($p < 0.0001$), age ($p = 0.003$), and admission to multi-ward admission ($p = 0.17$). Forward stepwise multivariate logistic regression produced two models. Model 1 included only historical exposure to tobacco smoke. Model 2 included both historical exposure to tobacco smoke and age, while multiple-ward admission was omitted. In Model 2, historical exposure to tobacco smoke had an odds ratio of 12.45 (95% CI: [3.14–49.36]), and age had an odds ratio of 3.18 (95% CI: [1.03–9.88]) for children aged 6 to 11 years, and 4.57 (95% CI: [1.40-14.96]) for those 12 years old and older, all compared to children less than 2 years old. Both predictors were adjusted for each other in this model. These results suggest that both increasing age and history of exposure to tobacco smoke are associated with a higher likelihood of experiencing long COVID symptoms (Table 4).

Discussion

The present study was conducted to identify long COVID symptoms among children and adolescents admitted to hospitals in Bushehr, Iran, in 2021–2023 and compare them with the non-affected group. In this study, 32.6% of the COVID-19-infected group had at least one of the long-term symptoms of COVID. The most prevalent reported symptoms included fatigue, impaired attention or concentration, depression or anxiety and hair loss respectively. In the non-affected group, no one reported long-term COVID symptoms. Asadi-Pooya et al. (2021) conducted a study on 58 children and adolescents with the mean age of 12.3 years old in Shiraz, Iran. They reported the prevalence of long COVID as 44.8%. In this study, individuals reported symptoms of fatigue, shortness of breath, exercise intolerance, weakness and walking intolerance, respectively [19]. In line with the present research, most of investigations conducted in this field have reported fatigue as the most prevalent symptom of long COVID [28–30]. Paying attention to persistent symptoms is of particular importance as two of the adolescents who participated in the present study experienced severe impaired attention or concentration, so that they had difficulty in studying and learning and, accordingly, one of them was under the physician's supervision. In our study, a significant relationship was

Table 2 Prevalence of long COVID symptoms by age groups in children and adolescents with COVID-19

Long symptoms of COVID (*N* = 46)		Age (year)				χ^2	*P*-value*
		> 2 (*N* = 7)	2–5 (*N* = 7)	6–11 (*N* = 17)	≥ 12 (*N* = 15)		
Impaired attention or concentration	Yes	0(0)	3(42.8)	7(41.4)	9(60)	7.345	0.061
	No	7(100)	4(57.2)	10(58.9)	6(40)		
Brain fog	Yes	0(0)	0(0)	0(0)	2(13.3)	2.998	0.392
	No	7(100)	7(100)	17(100)	13(86.7)		
Headache	Yes	0(0)	1(14.2)	5(29.4)	1(6.6)	3.848	0.251
	No	7(100)	6(85.8)	12(70.6)	14(93.4)		
Dizziness	Yes	0(0)	1(14.2)	2(11.7)	0(0)	2.813	0.513
	No	7(100)	6(85.8)	15(88.3)	15(100)		
Hair loss	Yes	3(42.8)	1(14.2)	6(35.2)	5(33.3)	1.486	0.796
	No	4(57.2)	6(85.8)	11(64.8)	10(66.7)		
Tingling	Yes	0(0)	0(0)	3(17.6)	2(13.3)	1.794	0.717
	No	7(100)	7(100)	14(82.4)	13(86.7)		
Earache	Yes	3(42.8)	0(0)	3(17.6)	1(6.6)	5.046	0.121
	No	4(57.2)	7(100)	14(82.4)	14(93.4)		
Rhinitis	Yes	0(0)	0(0)	0(0)	1(6.6)	2.675	0.630
	No	7(100)	7(100)	17(100)	14(93.4)		
Sore throat	Yes	0(0)	0(0)	1(5.8)	2(13.3)	1.555	0.866
	No	7(100)	7(100)	16(94.2)	13(86.7)		
Loss of taste or smell	Yes	0(0)	1(14.2)	3(17.6)	1(6.6)	1.794	0.717
	No	7(100)	6(85.8)	14(82.4)	14(93.4)		
Palpitations	Yes	0(0)	0(0)	1(5.8)	2(13.3)	1.555	0.866
	No	7(100)	7(100)	16(94.2)	13(86.7)		
Chest pain	Yes	0(0)	0(0)	1(5.8)	1(6.6)	1.224	1.000
	No	7(100)	7(100)	16(94.2)	14(93.4)		
Chest tightness	Yes	0(0)	0(0)	1(5.8)	1(6.6)	1.224	1.000
	No	7(100)	7(100)	16(94.2)	14(93.4)		
Cough	Yes	0(0)	1(14.2)	5(29.4)	1(6.6)	3.848	0.251
	No	7(100)	6(85.8)	12(70.6)	14(93.4)		
Shortness of breath	Yes	0(0)	0(0)	2(11.7)	2(13.3)	1.354	1.000
	No	7(100)	7(100)	15(88.3)	13(86.7)		
Abdominal pain	Yes	0(0)	4(57.2)	1(5.8)	1(6.6)	9.324	0.006¶
	No	7(100)	3(42.8)	16(94.2)	14(93.4)		
Nausea	Yes	0(0)	0(0)	1(5.8)	0(0)	2.425	1.000
	No	7(100)	7(100)	16(94.2)	15(100)		
Diarrhea	Yes	3(42.8)	0(0)	0(0)	0(0)	9.419	0.005¶
	No	4(57.2)	7(100)	17(100)	15(100)		
Weight loss	Yes	1(14.2)	1(14.2)	2(11.7)	1(6.6)	1.121	1.000
	No	6(85.8)	6(85.8)	15(88.3)	14(93.4)		
Change in appetite	Yes	1(14.2)	1(14.2)	5(29.4)	1(6.6)	2.802	0.448
	No	6(85.8)	6(85.8)	12(70.6)	14(93.4)		
Weakness	Yes	0(0)	0(0)	1(5.8)	0(0)	2.425	1.000
	No	7(100)	7(100)	16(94.2)	15(100)		
Joint and muscle pain	Yes	1(14.2)	1(14.2)	3(17.6)	2(13.3)	0.481	1.000
	No	6(85.8)	6(85.8)	14(82.4)	13(86.7)		
Depression or anxiety symptoms	Yes	1(14.2)	1(14.2)	7(41.1)	7(46.6)	3.504	0.306
	No	6(85.8)	6(85.8)	10(58.9)	8(53.4)		
Sleep disorders	Yes	1(14.2)	0(0)	1(5.8)	1(6.6)	1.555	0.866
	No	6(85.8)	7(100)	16(94.2)	14(93.4)		
Fatigue	Yes	2(28.5)	3(42.8)	8(47)	12(80)	6.654	0.080
	No	5(71.5)	4(57.2)	9(53)	3(20)		

Table 2 (continued)

Long symptoms of COVID (*N* = 46)		Age (year)				χ^2	*P*-value*
		> 2 (*N* = 7)	**2–5 (*N* = 7)**	**6–11 (*N* = 17)**	**≥ 12 (*N* = 15)**		
Skin rash	Yes	2(28.5)	1(14.2)	2(13.3)	0(0)	4.340	0.182
	No	5(71.5)	6(85.8)	15(88.3)	15(100)		
Other symptoms	Yes	1(14.2)	0(0)	0(0)	0(0)	4.199	0.304
	No	6(85.8)	7(100)	17(100)	15(100)		

*Fischer's Exact test

¶Significance $P \leq 0.05$

Table 3 Comparison of demographic variables between patients with and without long COVID symptoms

Variable		Long COVID symptom		χ^2	p-value
		Yes (*N* = 46) Number (percentage)	No (*N* = 95) Number (percentage)		
Sex	Female (*N* = 60)	19(41.3)	41(43.2)	0.044	0.835
	Male (*N* = 81)	27(58.7)	54(56.8)		
Age (year)	< 2	7(15.2)	28(29.5)	13.708	0.003¶
	2–5	7(15.2)	32(33.7)		
	6–11	17(37)	21(22.1)		
	≤ 12	15(32.6)	14(14.7)		
History of tobacco use	Yes or second-hand smoking	13(28.3)	3(3.2)	19.414	> 0.0001¶¶
	No	33(71.7)	92(96.8)		
ICU admission	Yes	9(19.6)	12(12.6)	1.175	0.278
	No	37(80.4)	83(87.4)		
Multiple-ward admission	Yes	25(54.3)	40(42.1)	1.86	0.172
	No	21(45.7)	55(57.9)		

¶Significance $P \leq 0.05$

¶¶Significance $P \leq 0.0001$

Table 4 Multivariate logistic regression to investigate the predictors (age, history of exposure to tobacco smoke) with the occurrence of long COVID symptoms in children and adolescents

Model	Predictor		B	Standard error (SE)	Wald statistics	*p*-value	Odds ratio (OR)	95% CI
Model 1[1]	History of exposure to tobacco smoke		2.49	0.67	13.75	< 0.0001	12.08	3.23–45.08
	Constant		-1.02	0.20	25.53	< 0.0001	0.35	-
Model 2[2]	Age (year)	< 2	-	-	11.51	0.009	1	-
		2–5	-0.12	0.64	0.035	0.852	0.88	0.25–3.11
		6–11	1.15	0.57	4.02	0.045	3.18	1.03–9.88
		12≥	1.52	0.60	6.33	0.012	4.57	1.40-14.96
	History of exposure to tobacco smoke		2.52	0.70	12.88	< 0.0001	12.45	3.14–49.36
	Constant		-1.70	0.46	13.40	< 0.0001	0.18	-

[1]Model 1 includes historical exposure to tobacco smoke

[2]Model 2 includes both historical exposure to tobacco smoke and age, adjusting for each other. Multiple-ward admission was omitted from Model 2

observed between the older age and having the history of smoking or being exposed to smoke and manifestation of long COVID symptoms. However, no significant correlation was found between factors such as gender, hospitalization in the intensive care unit and underlying diseases and manifestation of long COVID symptoms, which was inconsistent with other studies, probably due to differences in the methodology, sample size and research population characteristics. In line with our study, Osmanov et al. (2022) reported that manifestation of long COVID symptoms was correlated with older age [31]. Our study indicated a correlation between the older age and manifestation of long COVID symptoms and no correlation between the gender and manifestation of long COVID symptoms, which was consistent with results of Adler et al. (2023) [32]. However, other investigations have considered female gender as a risk factor for long COVID [33–35], two of which were conducted on adults. Considering different age groups could be the reason for obtaining conflicting results.

The present research showed a correlation between having the history of smoking and manifestation of long COVID symptoms, which was consistent with results of Barthélémy et al. (2022) [36]. Inconsistent with our study, Paterson et al. reported no correlation between the manifestation of long COVID symptoms and smoking [37] and explained that considering relatively young patients with mild COVID-19 could be the reason for this finding. In our work, there was difference between the manifestation of long COVID symptoms in different age groups, which was in line with the study by kikkenborg et al. (2022) in Denmark [20]. Contrary to the present research, some studies [19] have reported admission to the intensive care unit (ICU) as a risk factor for long COVID symptoms. The reason for this conflict could be attributed to the smaller number of people who had to be admitted to the ICU in our research. The present study indicated no correlation between underlying diseases and long COVID, which was somewhat in contradiction with other studies [38, 39], the reason for which could be attributed to the small sample size in our work. Also, the data obtained in most of the investigations were based on participants' self-report, which may have been under- or over-estimated. Our results showed a significant correlation between the length of hospital stay and manifestation of cough, weight loss and depression or anxiety as long COVID symptoms, so that the probability of manifestation of these symptoms in children and adolescents with long COVID was higher than that in the group with COVID-19 as the length of hospital stay increased. Considering that hospitalization is a stressful process for children [40], the more the length of hospital stay, the more tension and stress the person experiences. Therefore, the person is more likely to manifest depression or anxiety symptoms [41]. Due to the accepted impact of stress on digestive disorders [42] and, consequently, changes in one's appetite and weight, the manifestation of weight loss could be expected as the length of hospital stay increases and the person is exposed to tension and stress for a longer period of time.

In the present study, a correlation was observed between disease severity in the acute phase and length of hospital stay and manifestation of some symptoms. Some studies have reported a correlation between the manifestation of long COVID symptoms and disease severity in the acute phase of COVID-19 [43–45]. However, some others have not found any correlation between disease severity in the acute phase and long COVID [46]. Due to the lack of information in the medical records, disease severity for all patients in the acute phase could not be evaluated in the present study, we were only able to determine the severity of symptoms in patients with long-term covid; so, only the correlation between disease severity and manifestation of each symptom was assessed.

Strengths and limitations

Comparing the group of hospitalized children and adolescents due to covid-19 and comparing them with the group of the same age and gender without the disease was one of the strengths of this study. Incomplete recording of medical data during hospitalization in some cases and as a result our inability to record all physiological/medical data was among the limitations of our study. The obtained results were based on the patient statement. Thus, future studies should investigate and evaluate their physical and medical details after recovery. Limited access to the records of hospitalized children and adolescents and their incomplete list, unavailability of a number of records and shortage of the required data in the records was another limitation of this study. Therefore, findings of the present research may not represent all children and adolescents with long COVID in Bushehr.

Conclusions

Contrary to what was initially thought, children and adolescents were also affected by COVID and its complications. The prevalence of long-term COVID symptoms among children hospitalized for COVID-19 was 32.6%. The most commonly reported symptoms included fatigue, impaired attention or concentration, depression or anxiety, and hair loss. Different age groups showed variations in long-term symptoms: diarrhea was more frequent in children under 2 years, while abdominal pain was more common in those aged 2–5 years. A significant correlation was found between the severity of acute COVID and the persistence of muscle and joint pain, as well as between the length of hospital stay and symptoms such as cough, weight loss, and depression or anxiety. Older age and a history of smoking or exposure to tobacco smoke were identified as risk factors for long COVID.

Implications for research and practice

Findings of studies on this pandemic and its complications, even after it ends or is controlled, could provide good information for dealing with future pandemics, especially in the pediatric population. Conducting research on COVID-19 and long COVID is of particular importance for understanding the full course of this disease and its effects on patients after recovery. Informing patients, their families and the health care providers about the most prevalent symptoms after recovery from the acute phase of covid and the possibility of long-term covid occurrence can help to better manage the disease and long-term covid symptoms in infected patients. Long-term access to health care and social and financial support for patients with long COVID should be taken into account by policy makers and health managers.

Abbreviations

Csi-4	Children symptom inventory-4
HRCT	High Resolution computed Tomography
COVID-19	Coronavirus Disease 19
PCR	The Polymerase Chain Reaction
PCFS	Post-Covid-19 Functional Status Scale Manual
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SPO2	Saturation of Peripheral Oxygen
WHO	World Health Organization

Supplementary Information

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Supplementary Material 1

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Author contributions

MR, NM, GH, MS: Research design ; MS, AN: data collection; MR, NM, GH, MS: research execution by; NM: data analysis; MR, NM, GH, MS: documentation; and MR and MS primary responsibility for the final content. All authors reviewed the manuscript. All the authors have read and approved of the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the ethics committee (code: IR.BPUMS.REC. 1402.038) of Bushehr University of Medical Sciences, Bushehr, Iran. Informed consent was obtained from all the participants involved in the study or their legal guardians. The authors do not have any conflict of interest to declare.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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