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Impact of Seasonal Variations on the Hemostatic System in COVID-19

T.A. Bobomuratov, M.A. Bakirova, M.A. Ernazarova
Tashkent State Medical University, 2nd Shifokorlar street, 2, 100109, Tashkent, Uzbekistan

Annotation. At present, improving medical care for children during the recovery period after COVID-19, reducing post-recovery complications, and preventing their occurrence remain a priority direction in both scientific and practical pediatrics. The causative agent of COVID-19 induces inflammation and enhances blood coagulation. Researchers have warned that SARS-CoV-2 may damage blood vessels in children, potentially leading to the future development of hypertension, pulmonary hypertension, stroke, and chronic kidney disease.
Keywords: COVID-19, hypercoagulability, children, season.

At present, optimizing medical care for children during the post–COVID-19 recovery period, with particular attention to reducing complications and preventing their recurrence, remains a priority area of both scientific research and practical pediatrics[3]. In this regard, the World Health Organization (WHO) has identified the organization of diagnostic and therapeutic support for pediatric patients recovering from COVID-19 as a key strategic objective. Although various approaches aimed at improving the health status of this patient population have been developed and tested, their overall effectiveness remains limited, and the heterogeneity of clinical complications and manifestations necessitates the use of targeted, pathogenetically oriented therapy[4]. Currently, the question of the efficacy of nonspecific preventive measures aimed at enhancing the body's defense mechanisms in children remains highly relevant. Therefore, the most important task is the development of preventive programs focused on reducing disease incidence, shortening the duration and severity of illness, strengthening resistance to infections, improving the overall health of the younger generation, and enhancing their quality of life[1].

Investigations conducted by researchers have demonstrated that the causative agent of COVID-19 induces inflammation and enhances blood coagulation. C. Diorio and colleagues reported that in children infected with SARS-CoV-2, despite mild or absent clinical manifestations of COVID-19, there was a 38% increase in the biomarker sC5b9, an indicator of complement activation associated with vascular injury [2]. This finding corresponds to the clinical and diagnostic criteria of thrombotic microangiopathies—microvascular disorders characterized by intravascular coagulation—which are considered a potential cause of severe COVID-19 progression in adults. Scholars have cautioned that SARS-CoV-2 may damage the vascular system in children, potentially predisposing them to long-term sequelae such as arterial hypertension, pulmonary hypertension, ischemic stroke, and chronic kidney disease [5].

Objective of the study: To assess the state of the hemostatic system after coronavirus infection under different seasonal conditions.

Materials and methods: The study included 129 pediatric patients (main group) permanently residing in Tashkent City and 40 healthy children (comparison group). The control group comprised 40 practically healthy children belonging to health categories I and II. In accordance with the study objective, a comparative analysis of the hemostatic system was performed during the recovery (rehabilitation) phase in children who had experienced coronavirus infection. A total of 129 children were followed dynamically on an outpatient basis for one year, with comprehensive clinical and laboratory examinations conducted twice during the year.

During the comprehensive clinical and laboratory examination of the children, the medical records of patients previously treated in inpatient settings were retrospectively analyzed. Physical examination and clinical observation were performed, and a series of laboratory investigations—including complete blood count, biochemical, immunological, and coagulation (coagulogram) analyses—were conducted. In addition, chest radiographic examination was carried out.

Following discharge from the hospital, during the early recovery period (ranging from 15 to 30 days after acute illness), the majority of children reported persistent residual symptoms. The study assessments were performed on average 24.8 ± 2.8 days after disease onset. Depending on the severity of the initial COVID-19 course, children frequently presented with general fatigue, pain in the extremities, tachycardia,

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and chest discomfort. Notably, despite all patients with moderate and severe disease testing negative for SARS-CoV-2 by polymerase chain reaction (PCR) at the time of follow-up, these clinical findings indicated a complicated and protracted early convalescence. Such manifestations suggest ongoing pathophysiological processes—most likely related to persistent inflammatory and vascular changes—that continue beyond viral clearance.

These observations emphasize the need for careful post-discharge monitoring and structured rehabilitation programs for pediatric patients recovering from moderate to severe COVID-19. Persistent symptoms in the early convalescent phase may serve as early markers of subclinical cardiovascular or hemostatic dysfunction, reinforcing the importance of laboratory and functional assessment of the coagulation system and vascular status in this population.

In the majority of children, persistent astheno-neurotic symptoms — including headache, sleep disturbances, generalized fatigue, reduced attention span, and mood instability — as well as functional gastrointestinal disorders were observed during the early recovery period. General fatigue was reported in 78.7% of children who had experienced a moderate course of COVID-19 and in 100% of those who had suffered a severe course. Furthermore, 84.2% of children with severe disease complained of episodes of rapid heartbeat (tachycardia).

The frequency of pain in the extremities showed a clear relationship with the severity of the acute illness: it was reported in 16.6% of children after mild disease, in 78.8% after moderate disease, and in 55.2% after severe COVID-19 (Figure 1). Although the absolute frequency was highest in moderate cases, the persistence of extremity pain even after severe disease underlines the heterogeneity of post-infectious musculoskeletal involvement and its possible link to systemic inflammatory and vascular alterations.

These findings highlight the importance of targeted neurological and gastrointestinal evaluation during the convalescent phase, especially for children who experienced moderate to severe COVID-19. The high prevalence of neurovegetative complaints and functional digestive disturbances indicates the need for comprehensive rehabilitation approaches, including psychological support, autonomic nervous system assessment, and monitoring of gastrointestinal function to ensure complete recovery.

We analyzed the characteristics of the autonomic nervous system in children, focusing specifically on skin condition, sleep patterns, dermographism, and allergic reactions. The results of the study demonstrated that among children who had experienced COVID-19, 24.8% (n = 32) presented with dry and pale skin, while 34.1% (n = 44) exhibited increased sweating and hyperhidrosis, manifested by moist palms and soles.

These findings indicate a notable degree of autonomic dysfunction in the post-COVID-19 recovery phase, reflecting possible dysregulation of peripheral vascular tone and sweat gland activity. Such manifestations are consistent with previous observations that SARS-CoV-2 may induce prolonged imbalance within the autonomic nervous system in pediatric patients, potentially contributing to persistent fatigue, sleep disturbances, and altered thermoregulatory responses. Early recognition and assessment of these signs can inform tailored rehabilitation strategies aimed at restoring autonomic stability and improving overall functional recovery.

Hyperhidrosis was observed to occur 2.67 times more frequently in children who had experienced a severe course of the disease compared with those with very severe and mild forms, and 4.95 times more often compared with children who had mild COVID-19. Following coronavirus infection, children commonly presented with restless and shortened sleep, occipital headache, and increased fatigue.

Figure 1.

General characteristics of the early recovery period in children after COVID-19

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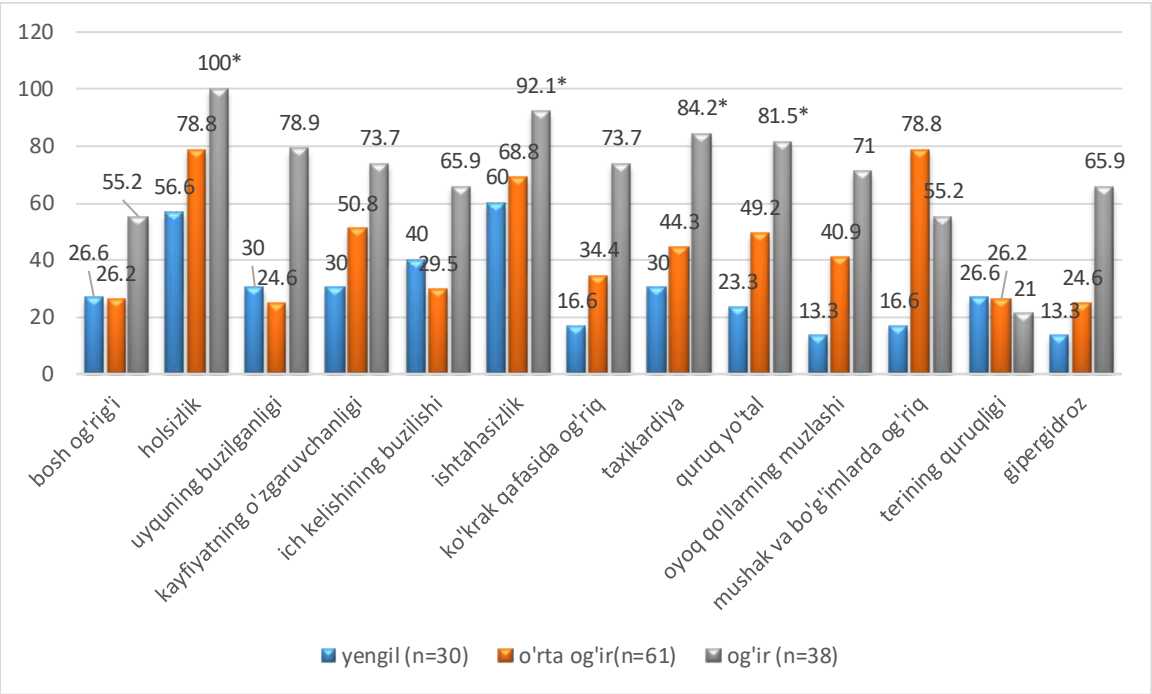

Note: Differences between apparently healthy children and patients were statistically significant at $p < 0.05$.

During the study, we also analyzed the seasonality of coronavirus infection among the pediatric cohort. According to our findings, 32.5% of the examined children developed the disease during the summer months, 27.1% in autumn, 20.9% in spring, and 19.4% in winter. When the severity of illness was evaluated in relation to seasonal distribution, the analysis revealed distinct variations in disease course depending on the time of year.

According to the analysis, moderate and severe courses of infection occurred during the summer months 5.75 and 3.75 times more frequently, respectively, compared with mild cases; in autumn, the corresponding frequencies were 9.7 and 4.0 times higher than mild cases. In contrast, during the winter season, mild disease was observed 1.2 and 2.2 times more frequently than moderate and severe forms, respectively, while in spring, mild cases were recorded 1.3 and 2.02 times more often than moderate and severe cases. The seasonal analysis thus demonstrated that severe forms of COVID-19 in children were more frequently observed under warm climate conditions, particularly during the summer and autumn months.

Table 1.

Seasonal Frequency of COVID-19 Severity in Children (M ± m)

Fasllar	O‘tkazilgan Covid-19ni og’irlik darajasi					
	Yengil (n=30)		o‘rta og‘ir (n=61)		og‘ir (n=38)	
	abs	M±m	abs	M±m	abs	M±m
Qish	11	36,7 ± 8,8	9	14,8 ± 4,5*	5	13,2 ± 5,5*
Bahor	12	40 ± 8,9	9	14,8 ± 4,5*	6	15,8 ± 5,9*
Yoz	4	13,3 ± 6,2	23	37,7 ± 6,2*	15	39,5 ± 7,9*
Kuz	3	10 ± 5,5	20	32,8 ± 6*	12	31,6 ± 7,5*

Note: * — statistically significant difference compared with mild form, *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Comparative analysis of coagulation system parameters in children under follow-up during the recovery phase revealed a number of alterations compared with healthy controls. These changes manifested as compensatory hypercoagulation in 30% of cases, subcompensated hypercoagulation in 41.8%, hypercoagulation in 22.4%, and hypocoagulation in 5.4%. Among children recovering from COVID-19, subcompensated changes in the hemostatic system were most frequently observed, particularly during the summer (17.8%, 42.6%) and autumn months (13.2%, 31.5%), where their prevalence was 2.5-fold ($p < 0.001$) and 4.6-fold ($p < 0.001$) higher, respectively, compared with winter and spring.

During these warmer months, the hemostatic system also demonstrated a greater tendency toward hypercoagulation: blood viscosity indices were increased in 11.6% of children, which was 7.7 times higher

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than in winter ($p < 0.01$) and 3.7 times higher than in spring ($p < 0.001$). By contrast, during winter and spring, compensatory patterns of hemostasis predominated (28.2% and 46.1%, respectively).

According to literature data, these alterations are largely attributable to the damaging effect of SARS-CoV-2 on the vascular endothelium, which disrupts normal coagulation regulation and promotes a prothrombotic state. In our opinion, environmental factors, such as increased fluid loss and insufficient hydration during hot climatic conditions, may further aggravate these hemostatic shifts, amplifying the risk of hypercoagulability in children recovering from COVID-19.

Conclusion: Coronavirus infection in children is accompanied by vascular injury and significant alterations in the hemostatic system, with climatic conditions exerting a notable influence on these changes. Hot and dry climates are associated with a more severe course of the disease, likely due to enhanced dehydration and vascular stress, which may exacerbate endothelial damage and promote hypercoagulability.

Coronavirus infection in children is associated with endothelial injury and pronounced alterations in the hemostatic system, which may persist beyond the acute phase of the disease. Our findings indicate that climatic conditions, particularly hot and dry environments, contribute to a more severe clinical course, likely through increased fluid loss, impaired vascular regulation, and enhanced hypercoagulability.

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