MEDICAL REHABILITATION AND INFECTIOUS DISEASES IN CHILDREN

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Today, medical rehabilitation is undergoing significant transformation. The new system built around the biopsychosocial model includes assessment of physical constraints and rehabilitation diagnosis, determination of rehabilitation potential, formulation of goals and objectives of individual interventions, development of rehabilitation plans, and progress evaluation. All of these rehabilitation components can be implemented using a personalized, problem-oriented, multidisciplinary approach, which is now being actively introduced into clinical practice. The current pandemic of the novel coronavirus infection has demonstrated that medical rehabilitation is crucial for convalescents. However, its principles and techniques have not been fully elaborated yet. This review describes the current state of medical rehabilitation of children with or after infectious diseases and identifies its avenues and prospects.

Keywords: children, rehabilitation, infectious diseases, ICF, telemedicine, biopsychosocial model, personalized approach, COVID-19

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МЕДИЦИНСКАЯ РЕАБИЛИТАЦИЯ И ИНФЕКЦИОННЫЕ БОЛЕЗНИ У ДЕТЕЙ

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Медицинская реабилитация в наши дни претерпевает существенные изменения. Эта новая, выстраиваемая на основе биопсихосоциальной модели, система, включает в себя оценку ограничений жизнедеятельности, определение реабилитационного диагноза и реабилитационного потенциала, формирование цели и отдельных задач реабилитационных вмешательств, построение и осуществление плана реабилитационных интервенций с последующей оценкой достигнутых результатов. Все эти действия возможны в условиях реализации персонифицированного, проблемно-ориентированного и мультидисциплинарного подходов, которые сейчас активно внедряются в клиническую практику. Пандемия новой коронавирусной инфекции определила жизненную необходимость медицинской реабилитации реконвалесцентов инфекционных болезней, принципы и технологии которой не отработаны до настоящего времени. В обзоре представлено состояние современной медицинской реабилитации в детской инфектологии, специфика медицинской реабилитации у детей в условиях инфекционного процесса и после его завершения. Определены основные направления медицинской реабилитации детей с инфекционными болезнями и перспективы ее развития.

Ключевые слова: дети, реабилитация, инфекционные заболевания, МКФ, телемедицина, биопсихосоциальная модель, персонифицированный подход, COVID-19

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The conventional approaches to medical rehabilitation adopted in Russia are undergoing significant transformation toward the biopsychosocial model of disease that public healthcare is yet to fully incorporate. Unlike the classical biomedical model, the biopsychosocial model is not constrained by the nosological approach and sees disease as a complex of biological, psychological and social processes [1]. Apart from focusing on the biological factors implicated in disease, biopsychosocial rehabilitation actively exploits psychological and social approaches to recovery and thus can exert broader effects on sanogenesis.

In the past decade, this new model of medical rehabilitation has been actively implemented in Russia. New rehabilitation specialties have emerged, including physical medicine and rehabilitation doctors and rehabilitation nurses indispensable to the multidisciplinary rehabilitation team. Professional standards have been elaborated for healthcare workers engaged in ergotherapy (ergotherapists, ergospecialists), physical therapy (physical therapists, kinesiotherapists), speech therapy, and medical psychology [2, 3].

According to the now effective legislation on medical rehabilitation, the latter must be multidisciplinary in nature and utilize the International Classification of Functioning, Disability and Health (ICF) [4].

Being a representation of the biopsychosocial disease model, ICF provides a framework for rehabilitation: based on

the ICF-coded diagnosis, the ultimate goal of rehabilitation and its smaller objectives are identified, the rehabilitation plan is designed (considering the rehabilitation potential) and rehabilitation outcomes are evaluated [5].

Developmental issues are a serious ramification of childhood diseases; therefore, a series of consecutive rehabilitation courses may be needed for children with a past history of disease, each course being a continuation of the previous one. Children may develop concurrent debilitating conditions that together produce a devastating effect. Establishing a good rapport with children and their parents is critical for successful pediatric rehabilitation. Immediate family (ICF code e310) is an environmental factor that has a tremendous impact on the child's health. Many problems experienced by the child may be linked to the individual attitudes perpetuated in the family (ICF code e410). Another important contributor is physical environment (Products and Technology, ICF code e1): skills and activities are learnt through the interaction with the environment, which is ideally fosters development and is a powerful rehabilitation tool. Restricting children in their basic activities, including mobility, may preclude other activities and cause secondary damage to cognitive development.

The medical rehabilitation of today is very much different from what it was in the past. Its concept raises the need for rethinking and refining rehabilitation strategies and techniques. Approaches to rehabilitation are changing in every medical field, including the domain of pediatric infectious diseases.

Pediatric infectious diseases are very common, making up 90% of childhood diseases [6, 7]. The most prevalent are acute respiratory infections: their incidence among children is 2.5–2.9 times higher than among adults [8]. The impact of pediatric infections on child health and development is difficult to underestimate, considering current trends in their incidence and the spread of the novel coronavirus infection, which has convincingly shown that infections are still one of the primary threats to mankind. Today, old infections are resurfacing and novel infections are emerging. Antimicrobial resistance, human microbiome transformation and herd immunity fluctuations remain a serious challenge. The economic burden of infections is growing [9, 10].

This review covers Pubmed, e-library and Cochrane library publications of the past decade focusing on the medical rehabilitation of children with a history of infectious diseases.

Neuroinfections

Neuroinfections are among the leading contributors to pediatric morbidity from infectious diseases. Half of pediatric patients with neuroinfections develop disabilities with persistent organic symptoms in the residual period [11, 12]. Poor outcomes may be associated with the child's age, the corresponding stage of brain development and vulnerability of some CNS structures. Pre-existing pathology of the nervous system can aggravate the damage [11].

High demand for rehabilitation is associated with severe sequelae of neuroinfectious diseases; some authors emphasize the importance of starting rehabilitation in the acute stage of the disease because the early commencement of rehabilitation therapy may determine rehabilitation potential and prevent complications or disability [13].

According to publications investigating the outcomes of neuroinfections, mechanisms underlying neurological deficit and cognitive disorders remain understudied, meta-analyses are scarce and there are certain difficulties in formulating conclusions [14–17]. The long-term neurological consequences of neuroinfections that reduce the quality of the patient's life are observed in 25–63% of cases [17, 18]. While studying the outcomes of neuroinfections, many authors focus on immunization, premorbidities, length of hospital stay, timeframe and choice of antibacterial or glucocorticoid therapy, nutritional status, and dehydration [14, 19–22]. Unfortunately, the effects of rehabilitation on the outcomes of neuroinfection are barely discussed.

Children with a past history of neuroinfection experience a variety of health problems differing in form and severity. Those include cognitive impairment, autonomic disorders, attention deficit/hyperactivity disorder, central or peripheral paresis, coordination disorders and speech impairment, epilepsy, etc. [6]. The meta-analysis of 868 meningococcal meningitis cases [17] revealed the presence of residual symptoms in 18% of the patients manifesting as hearing loss (5.4%), skin scarring (5.4%), renal dysfunction (2.6%) or seizures (2.5%). Cerebrasthenia was observed in 40–85% of convalescent children with aseptic meningitis, whereas reduced working memory was reported in 24% of cases; these conditions persisted for up to 6 months in 20–40% of the patients [23]. Among other neuroinfection sequelae reported in the literature are increased intracranial pressure (13%), diencephalic (16%) and focal (10%) manifestations. Neurasthenia (35%), increased intracranial pressure (19%) and symptomatic epilepsy (3%) can last for over a year following the infection [6]. Significant functional decline is observed after infectious encephalitis [24, 25]. Almost 80% of patients with encephalitis suffer from neuropsychological impairment. There are reports of attention and behavioral deficits and emotional impairment continuing for 3 years after the acute phase of the disease [26, 25].

According to an American study, 37 of 55 children infected with tick-borne encephalitis in 2004–2008 had cognitive deficit, headaches, fatigue and irritability 2–5 years after the infection. Parent and teacher surveys revealed that over one-third of the affected children had behavioral problems, motivational deficiency and reduced working memory [27]. Similar findings were reported by Swedish, Chinese and Russian researchers. Attention deficit/hyperactivity disorder was diagnosed in 50% of children with a past history of tick-borne encephalitis in both early and late postinfectious periods [27–29]. Another concern is postinfectious epilepsy. Over half of children infected with encephalitis develop seizures in the acute stage of the disease [30]. Besides, patients with postinfectious epilepsy are at increased risk for depression and anxiety [31].

According to the nationwide population-based cohort study that relied on the data from Danish registries collected in 1980–2008, adults with a past history of childhood neuroinfection are less educated, less financially secure, less involved socially and are dependent on disability payments [32].

Canadian researchers attempted to conduct a meta-analysis of 20 studies on rehabilitation after infectious encephalitis extracted from 12,737 sources. Nine of the included studies investigated the effects of cognitive therapy, 5 looked at behavioral therapy, 2 focused on physical therapy and 4 on complex rehabilitation involving 2 or more types of therapy. Unfortunately, due to small sample size (no more than 25 patients in each case) and clinical and methodological heterogeneity, the meta-analysis failed [33, 34].

Another study demonstrated a reduced quality of life 6 months after encephalitis for both children and adults [35, 36].

The following conditions are reported in children with a medical history of herpes simplex encephalitis: diverse neurological symptoms (tetraparesis, hydrocephalus, symptomatic epilepsy, developmental delay) in the first year of

Table. Domains of functional and structural damage in convalescent children after infectious disease (from [64], printed by permission of the authors)

Clinical examples (diagnoses)	Domains and functional/structural damage categories	
	Code	Domains and categories
Prolonged neonatal jaundice	b 598.1	Mild disorders of the digestive, metabolic and endocrine systems, other specified
Hepatitis B	b 515.1 b 525.1 b 535.1 s560.17	Mild disorders of digestive functions Mild disorders of defecation functions Mild disorders of sensations associated with the digestive system Mild changes to liver structure
Chronic CMV hepatitis resulting in fibrosis	b 515.2 b 525.2 b 535.2 s560.27	Moderate disorders of digestive functions Moderate disorders of defecation functions Moderate disorders of sensations associated with the digestive system Moderate changes to liver structure
Highly active autoimmune hepatitis, developing cirrhosis	b 515.3 b 520.3 b 525.2 b 530.3 b 535.3 b 550.2 b 430.3 b 435.3 s560.37	Severe disorders of digestive functions Severe disorders of assimilation functions Severe disorders of defecation functions Severe disorders of weight maintenance functions Severe disorders of sensations associated with the digestive system Moderate disorders of thermoregulatory functions Severe disorders of hematological system functions Severe disorders of immunological system functions Severe changes to liver structure
TTV hepatitis in the presence of hepatic steatosis, metabolic syndrome, asthma	b 515.3 b 520.3 b 540.3 b 545.2 b 555.2 b 440.1 b 455.2 b 460.2 s560.37	Severe disorders of digestive functions Severe disorders of assimilation functions Severe disorders of general metabolic functions Moderate disorders of water, mineral and electrolyte balance functions Moderate disorders of endocrine gland functions Mild disorders of respiration functions Moderate disorders of exercise tolerance functions Moderate disorders of sensations associated with cardiovascular and respiratory functions Severe changes to liver structure
Salmonella-induced dysbiosis	b 515.2 b 520.2 b 525.2 b 530.2 b 535.2 b 540.2	Moderate disorders of digestive functions Moderate disorders of assimilation functions Moderate disorders of defecation functions Moderate disorders of weight maintenance functions Moderate disorders of sensations associated with the digestive system Moderate disorders of general metabolic functions
Enteroviral meningitis	b 126.1 b 130.1 b 134.1 b 147.1	Mild disorders of temperament and personality functions Mild disorders of energy and drive functions Mild disorders of sleep functions Mild disorders of psychomotor functions
Haemophilus meningitis	b 126.3 b 130.3 b 134.3 b 147.3 s130.27	Severe disorders of temperament and personality functions Severe disorders of energy and drive functions Severe disorders of sleep functions Severe disorders of psychomotor functions Moderate changes to the structure of meninges
Obstructive bronchitis	b 440.1 b 435.1	Mild disorders of respiration functions Mild disorders of immunological system functions
Chronic bronchiolitis, diffuse bronchiectasis, stage 1 chronic respiratory failure	b 410.2 b 440.2 b 435.2 b 455.2 b 460.2 s410.27 s430.273	Moderate disorders of heart functions Moderate disorders of respiration functions Moderate disorders of immunological system functions Moderate disorders of exercise tolerance functions Moderate disorders of sensations associated with cardiovascular and respiratory functions Moderate changes to the structure of cardiovascular system. Moderate bilateral changes to the structure of respiratory system

life; motor skills disorder and a speech and language delay in children aged 1-3 years; ataxia, neurosis, neurosis-like states in preschoolers; emotional, volition and hypothalamus disorders, and intellectual disability in school children [6].

Focal demyelination caused by infection can result in residual neurologic deficit in 30% of children or have a progressive course leading to severe polysyndromic neurologic deficit in 20% of cases. Spinal cord and peripheral nervous system infections often manifest as myelopathy, myelopolyneuropathy, polyneuropathy, facial neuropathy, and polyradiculopathy [6].

Rehabilitation after neuroinfection includes early mobilization, physical exercise, massage, speech therapy, psychotherapy, body positioning, prophylaxis of pressure ulcers, contractures, pneumonia, and thrombotic complications. Motor rehabilitation should be step-wise and include training of movement components, proprioception enhancement, simple associated movements, joints, and motor skills. Children with peripheral paresis associated with myelitis or poliomyelitis should undergo therapy with electrical stimulation, paraffin or ozokerite applications, general fitness physical and respiratory exercise, special exercises for the affected limb, and hydrokinesiotherapy. To relieve pain, alleviate autonomic and trophic disturbances and regain motor function, a variety of interventions are recommended, including two or four-cell tub baths, diadynamic, sinusoidal modulated and interferential currents, ultrasound therapy and phonophoresis, therapy with alternating magnetic fields, ozokerite applications, and a combination of magnet and laser therapy. Other options include kinesiotherapy, robotic therapy for motor function recovery, standing and walking frames, dynamic proprioceptive correction, speech therapy, and biolfeedback therapy [6].

Complex rehabilitation and follow-up care are crucial for achieving complete recovery, especially when it comes to infants, whose immunity is underdeveloped and who are at risk for serious complications [13].

Acute gastrointestinal infections

Acute gastrointestinal infections are leading in incidence, both in Russa and worldwide [37, 38]. In 20–30% of cases, acute gastrointestinal infections provoke functional gastrointestinal disorders [13]. It is known that acute intestinal infections cause dysbiosis and allergies, change the reactivity of the immune system, triggering autoimmune disorders, promote gastrointestinal pathology, have an adverse effect on the physical and mental development of the child [39]. In up to 30% of cases, children develop irritable bowel syndrome following acute intestinal infection. There is evidence that 25% of children with acute infectious diarrhea are at high risk of gallbladder, pancreas and bowel dysfunction 6 months after the infection [39]. There are reports of exacerbations of atopic dermatitis and developmental delay in children recovering from intestinal infections, suggesting that rehabilitation should start as early as the subacute stage of infection [13].

The primary objectives of rehabilitation at each of its stages are as follows: treatment of intestinal dysbiosis using galvanic therapy of the abdomen with topically applied microelements or microwave diathermy [40–42]; correction of functional and morphologic changes of intestinal mucosa (ultrahigh-frequency therapy, low-energy laser irradiation [43]), restoration of colon motility and normal evacuation (amplipulse therapy, interferential therapy, diadynamic therapy, localized cryotherapy, massage [40]); management of asthenia and autonomic disorders (magnet therapy, resonance frequency therapy [44]); hydrotherapy [40].

There is a paucity of studies focusing on the rehabilitation of pediatric patients with postinfectious cardiovascular disorders although their incidence is quite high [45]. Cardiac pathology associated with infection poses a high risk of complications, raising the need for timely diagnosis and adequate rehabilitation [46, 47].

Novel coronavirus disease COVID-19

This infection typically has respiratory and gastrointestinal presentations in children and adolescents [48–50]. Respiratory viral coinfection is diagnosed in 11–46% of patients with COVID-19 [51]. Severe COVID-19 is often observed in very young children or those who have preexisting cardiovascular disorders, chronic pulmonary conditions, compromised immunity, etc. [51–54].

Rehabilitation is needed for children with COVID-19 who develop lung damage [55, 56], cardiovascular complications [49], neurologic [57] and gastrointestinal [58, 59] disorders. The broad spectrum of neurologic sequelae of COVID-19 comprises anosmia, ageusia/dysgeusia, acute Guillain-Barr– syndrome, cerebral and spinal damage [57]. Follow-up care and rehabilitation are required for children with postinfectious asthenia persisting for 1–2 months in 30% of patients. Clinically, it is manifested as increased fatiguability, malaise, mental and physical exhaustion [60, 61]. Regardless of the underlying mechanisms, forms and severity, damage to the nervous system that requires further rehabilitation manifests as asthenia, autonomic dysfunction, central or peripheral paresis, coordination impairment, seizures, and speech impairment.

Recent research has demonstrated that children with a past history of COVID-19 need rehabilitation regardless of the severity of disease (even when the disease is asymptomatic or mild). This is associated with the risk of functional impairment of respiratory and other systems. Rehabilitation includes physiotherapy, balneotherapy (pelotherapy), physical exercise, reflexotherapy, manual therapy, psychotherapy, etc. [62]. The principles of medical rehabilitation for children with COVID-19 are the same as for adults and account for small age and exercise tolerance [63].

Similar to other types of pediatric rehabilitation, medical rehabilitation of children with COVID-19 follows certain guidelines. Rehabilitation of children with COVID-19 is aimed at training and recovery of compensatory capacity of the bronchopulmonary and cardiovascular systems.

Rehabilitation for bronchopulmonary pathology associated with COVID-19 should include respiratory and psychological rehabilitation, nutritional support, and physical methods for managing bronchial obstruction syndrome (inhalation therapy, halotherapy) [50]. Respiratory muscle function can be supported through transcutaneous electrical stimulation of the diaphragm, mucostasis inhibition, huffing, and autogenic drainage. Rehabilitation techniques used in pediatric patients with COVID-19-associated neurological disorders depend on the child's age, the leading pathological syndrome, severity of respiratory disorders and can include muscle relaxation, motor skills training required for self-care, electrical muscle stimulation, motor correction, and therapy for neurasthenia. To restore bowel motility in children with COVID-19-associated intestinal disorders, amplipulse therapy, interferential therapy, localized cryotherapy, diadynamic therapy, massage, pine baths, and microwave diathermy (for children over 2 years of age) are recommended.

Is pediatric medical rehabilitation for infectious diseases sufficiently elaborated? Literature analysis reveals a dearth of publications on the effectiveness of both individual rehabilitation methods and complex approaches, as well as the almost complete absence of guidelines for load tolerance control. ICF is rarely used; there is no information about activity constraints and patient involvement; the impact of the environment, including parents and family, is not analyzed. There are no publications on the effectiveness of early rehabilitation in the intensive care setting. Obviously, medical rehabilitation of children with infectious diseases is still based on outdated biomedical approaches. The long overdue transition to the new model is mentioned in by a handful of authors, who provide rationale for personalized, problem-oriented and multidisciplinary approaches.

Special attention should be paid to the arguments advocating a personalized approach to the rehabilitation of children with infectious diseases that involves assessment of structural and functional damage using ICF categories [64]. The authors of the cited study conducted health assessment of 103 children discharged from the departments of respiratory, intestinal, neurological infections and hepatitis (see Table). Using ICF criteria, 5 patient groups were identified based on the severity of functional damage. Over 36% of the patients needed medical rehabilitation. The authors concluded that ICF had good potential as a tool for designing individual rehabilitation plans and controlling their implementation and effectiveness.

The cited publication was a pioneer study. It did not attempt to analyze factors limiting patient activity, patient involvement or the effects of the environment on patient progress.

The use of ICF in the therapy of children with mental conditions and hearing and speech disorders [65] and in designing rehabilitation plans for children with speech impairments [66] was discussed in earlier publications.

Some authors highlight the economic benefits of rehabilitation [67], which can significantly improve social adaptation and daily performance of children with a past history of neuroinfection [68]. It is believed that continuity, diversity and order of rehabilitation procedures at different stages of rehabilitation is key to successful recovery. It is also important to adjust the rehabilitation plan to the patient's condition and monitor their health throughout the rehabilitation process [69].

Recently, nutritional support has been recognized as an essential rehabilitation tool complementing physical therapy and psychotherapy in the hospital setting [70].

Parents and other family members play a tremendous role in the successful rehabilitation of the child; parents should be encouraged to get more involved in order to ensure a gradual, long-lasting positive effect of rehabilitation procedures [71].

There is a pressing need for an agency that would ensure effective patient routing based on the severity of their condition. Some authors stress that rehabilitation should be started as early as possible and be patient- and problem-oriented [72–75]. Recently, telerehabilitation has been actively discussed in the literature, including its potential as a method for controlling adherence and evaluating patient performance and general health [76–78].

New software for designing rehabilitation plans is emerging. A decision support system may be helpful in deciding on the extent of interventions for pediatric rehabilitation [79]. A good example here is a guidance and a parent's diary developed by British researchers for parents whose children had a history of meningitis [80]. Development of such rehabilitation tools for basic pediatric infections is a critical milestone in the adoption of the biopsychosocial approach to patient and their family.

CONCLUSION

There is a paucity of fresh systematic reviews and original research studies on the rehabilitation of children with infectious diseases. The majority of the identified publications only describe methods of pediatric rehabilitation after infection, which raises the need for high-quality research into this problem.

Still, studies of the biomedical approach to pediatric rehabilitation will not be of much help. Earlier, an unsuccessful attempt was made to conduct a meta-analysis of studies focusing on the rehabilitation of children after infectious encephalitis [34]. Approaches to rehabilitation can be systematized by using ICF as a classification system and the basis for formulating a rehabilitation diagnosis. It will be necessary to adopt a multidisciplinary approach to the diagnostic process (to assess physical activity constraints, patient involvement and the impact of environmental factors), set the goals and objectives of interventions and elaborate the plan for their implementation.

We hope that in the nearest future medical rehabilitation of children with infectious diseases will be systematized and assimilate new methodological approaches, thereby becoming more effective, improving the quality of life of patients and their parents, and creating economic benefits for the state by maintaining health of its citizens.

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