Genij Ortopedii. 2022. Vol. 28, no. 3. P. 425-430.

Original article

https://doi.org/10.18019/1028-4427-2022-28-3-425-430

Orthotic experience in spinal cord injury (case report)

D.L. Safronov✉, A.A. Kolyabin, A.A. Grischuk, A.K. Poverinov, M.A. Shongina, A.V. Mazaeva, V.R. Ramazanov

Children's Prosthetic Center "I want to walk", Moscow region, Ruza

Corresponding author: Denis L. Safronov, d.l.s@rambler.ru

Abstract

Relevance Traumatic spinal cord injury is a complex, urgent and multidisciplinary problem with a high percentage of disability and subsequent social exclusion. Treatment of neuroorthopedic pathologies is often associated with the need to use technical means of rehabilitation. The objective was to develop a successful orthosis for a patient with severe spinal cord injury. **Material and methods** The article describes a clinical case of a 16-year-old female patient with the outcome of a severe concomitant injury: lower paraplegia, sensory disturbances in the lower extremities and pelvic organ function. MRI of the spinal cord revealed cystic-glial changes and atrophy of the spinal cord at the Th10-12 level. **Results and discussion** With clinical signs of paraplegia and a complete spinal cord injury according to the instrumentation findings, the patient had poor prognosis for the recovery of motor functions in the lower limbs. One of the main tasks of medical rehabilitation of patients with spinal cord injury is the activation of movements and restoration of locomotion. The Hip-Knee-Ankle-Foot Orthosis (HKAFO) manufactured at the Center was intended for unloading, replacement and fixation. The device was light and strong due to greater use of carbon layers, equipped with functional hinges to prevent development of contractures, had a high corset for external stabilization of the body and double knee splint for safe standing. **Conclusion** For the paraplegic patient, the opportunity to stand and walk with the support using successful orthosis was important from both physical and psychosocial perspectives and allowed correction of contractures in the catamnesis.

Keywords: spinal cord injury, paraparesis, contractures, goniometry, rehabilitation, orthoses, orthotics, apparatus for body and limb

For citation: Safronov D.L., Kolyabin A.A., Grischuk A.A., Poverinov A.K., Shongina M.A., Mazaeva A.V., Ramazanov V.R. Orthotic experience in spinal cord injury (case report). *Genij Ortopedii*, 2022, vol. 28, no 3, pp. 425-430. https://doi.org/10.18019/1028-4427-2022-28-3-425-430

INTRODUCTION

Traumatic spinal cord injury is a complex, urgent and multidisciplinary problem [1] caused by significant complications associated with spinal cord injury, severe functional disorders leading to limited self-care and movement, loss of pelvic floor functions with resultant disability, social and psychological maladaptation of patients [2]. Young people of working age are more vulnerable to traumatic injuries of the spine and spinal cord with a high percentage of disability and social maladaptation [3]. Injuries to the spine and the spinal cord account for 0.8 to 20–26.2 % of all musculoskeletal injuries in adult population [2] with an incidence rate of 0.6 per 1000 people [4]. A.V. Zaletina et al. (2018) reported 0.2 cases of unstable and complicated injuries to the spinal column per 10,000 children in the Russian Federation [5]. Falls from a height (43.7 %), road traffic accidents (29.5 %), diving in shallow water (17.5 %) are the most common causes of spinal injuries [3].

Spinal injuries account for 10–20 % of all traumatic injuries of the nervous system [6]. Injuries to neural structures include concussion of the spinal cord, contusion of the spinal cord and/or spinal nerve roots, compression of the spinal cord and/or spinal nerve roots, partial and complete injury to the spinal cord and/or spinal nerves [7]. The type of spinal cord injury can only be determined retrospectively because of spinal shock in the acute period [7]. According to the standard Frankel/ASIA classification, 15 % of patients with traumatic spinal cord injury have complete motor and sensory impairment (ASIA type A) [3]. However, even an incomplete injury to the spinal cord would consign most patients to many years of suffering [8, 9].

Mobility problems are most common in spinal cord injury with the main mobility parameter being the ability to stand and walk [10]. Secondary conditions (diseases of the cardiovascular and respiratory systems, urinary tract infections, weight gain, decrease in bone mineralization, depression) can develop due to limited motor functions and lead to a significant decrease in the quality of life and a significant increase in the cost of medical care [11]. Movement recovery remains the most important task that determines the goals of rehabilitation [8]. The treatment of neuroorthopedic pathologies is often associated with the need for orthoses [12]. Orthoses are used for many diseases including the consequences of spinal cord injuries and poliomyelitis, cerebral palsy, post-traumatic defects of long bones and joint contractures, after bones and ligament operations; with congenital musculoskeletal anomalies [12, 13]. The timeliness of orthotics is an

important element in the effectiveness of treatment and medical and social rehabilitation of patients with osteoarticular pathology [14]. Traditional orthoses may appear bulky, large, unattractive and uncomfortable for children to wear considering the age and physical and biological characteristics of patients [15]. Therefore, modern orthoses are essential in neuroorthopedic pediatric practice to be developed on recent advances in material technology being light, flexible and comfortable supports that can improve the quality of life of young patients [15].

The objective was to develop a successful orthosis for a patient with severe spinal cord injury and poor prognosis for motor recovery of the lower limbs.

MATERIAL AND METHODS

All materials and methods are presented with the informed consent of the patient's legal representative and in compliance with the ethical principles of the Declaration of Helsinki Revision 2013.

Patient K., born in 2004, presented at the Prosthetics Center with complaints of inability to stand up, walk unassisted, having impaired sensation in the legs and pelvic floor dysfunction. The patient had a history of a road traffic accident she sustained in June 2014. She was referred to a trauma hospital and treated with diagnosis: Severe concomitant injury. Closed craniocerebral injury, concussion. Traumatic disease of the spinal cord, acute period. Frankel A score. ASIA A score. Paraplegia and pelvic floor dysfunction. Subarachnoid hemorrhage. Fracture of the pelvic bones: sacrum on the left, pubic bones, rupture of the sacroiliac joint on the left with a slight displacement. Closed displaced fracture of the middle third of the left femur. Bladder injury. Intrapelvic hematoma. Degloving wound of the left iliac region. Traumatic shock of the 2nd degree. She was on a ventilator, anti-shock, antibacterial and infusion therapy (with vascular and nootropic drugs) for 3 days. Surgical treatment performed included: closed reduction, nailing of the left femur; laparotomy, suturing the bladder wound. The patient received physiotherapy, thermotherapy, massage and exercise therapy in the subacute period. The girl was seen by a neurologist and an orthopaedic surgeon at the place of residence; she repeatedly had courses of rehabilitation with minimal dynamics observed in motor recovery. Physical examination showed complete passive and active movements in the upper limbs; valgus deformity of the lower extremities up to 6 degrees, pronounced hypotrophy of the muscles of the pelvic girdle, femurs and legs on both sides. Muscle strength in the muscles of the feet and legs was 0 points on the right and left and 2 points in hip flexors and extensors on the right and left. Arbitrary contraction of the anus was not noted. Muscle tone in the legs was reduced. She had medium, symmetrical tendon reflexes of the hands; none were seen in the lower extremities. Abdominal reflexes were elicited, of average liveliness, quickly depleted on re-examination. She had contractures of the hip, knee and ankle joints, goniometry parameters are presented in Table 1.

Table 1

Goniometry of major joints of the lower extremities

Joint	Motion	Normal	On the right	On the left
Hip	Flexion	75°	55°	60°
	Extension	140°	185°	185°
	Abduction	50°	40°	40°
Knee	Flexion	40°	30°	30°
	Extension	180°	175°	175°
Ankle	Flexion	130°	125°	130°
	Extension	70°	85°	90°

No pathological reflexes were revealed. Tactile and pain sensitivity was absent in the anal region, feet, legs, middle and lower third of the femur. Hypesthesia was noted in the upper third of the femur, abdomen (below the level of the T10 dermatome). The girl could sit unassisted, she had severe lumbar hyperlordosis (compensatory), scoliosis (Fig. 1), tension and pain on palpation of the paravertebral muscles in the thoracic and lumbar spine.

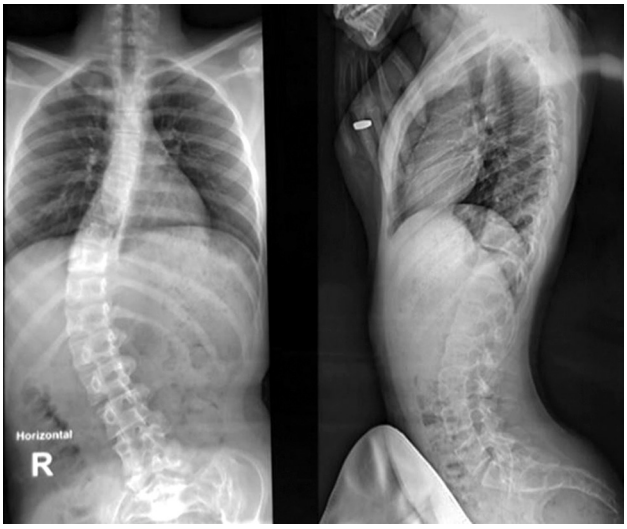

Fig. 1 AP and lateral views of the thoracic and lumbar spine showing the pelvis (in the supine position), scoliosis 34 degrees, with the apex at Th12, lordosis 27 degrees

She could not stand assisted and unassisted, used the wheelchair and had no bladder and bowel control. Higher cortical functions corresponded to her age level. The Hauser ambulation index graded 8 (restricted to wheelchair; able to transfer self independently) [16]. The Barthel index rated 30 (pronounced dependence on

outside care) [17]. FIM score (Functional independence measure): the total score for motor functions was 37 (the maximum score of 91), the girl could perform 23 % of the activities independently; intellectual functions graded 35 (maximum value). The weight of the girl was 45 kilograms. MRI scan of the spinal cord showed myelopathy of Th10-L1 in the acute period that transformed into cystic-glial changes with atrophy of the spinal cord at the level of Th10-12 and adhesions in the dural sac (Fig. 2, 3).

Based on complaints, past history, physical examination the patient was diagnosed with traumatic disease of the spinal cord, late recovery period. ASIA A scale. Cystic-glial changes with atrophy of the spinal cord at the Th10-12 level. Lower distal paraplegia. Hyperlordosis. Right-sided scoliosis of the thoracolumbar spine grade 4. Flexion contractures of the hip, knee and ankle joints. Pelvic floor dysfunction. The multidisciplinary team of the center (orthopedist, neurologist, prosthetists, occupational therapist) set out to teach the girl ambulate independently using technical means of rehabilitation and prevent development of contractures of major joints of the lower extremities. To solve the above problems, the laboratory of the center developed an apparatus for the trunk and lower limbs.

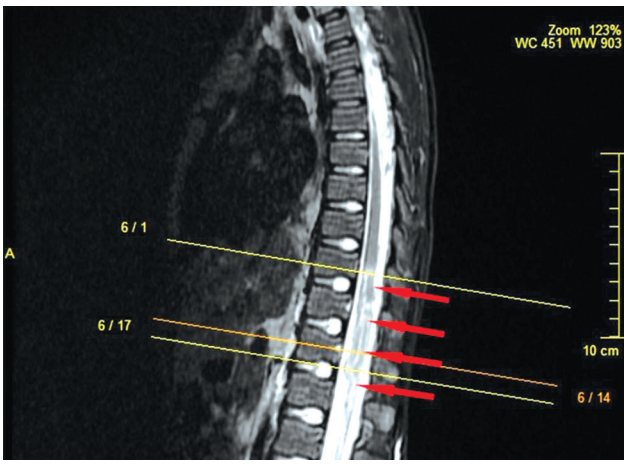

Fig. 2 MRI scan of the spinal cord, acute period. Sagittal T2W_TSI images showing myelopathy at the Th10–L1 level

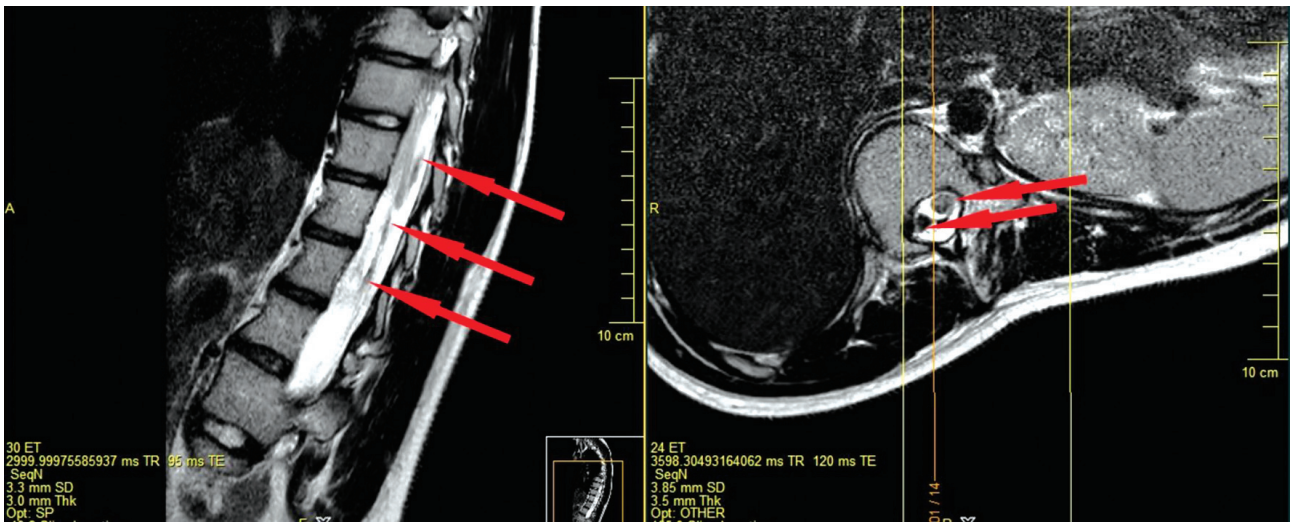

Fig. 3 MRI scan of the spinal cord performed during the recovery period. Sagittal and axial T2W_TSI images showing cystic-glial changes, atrophy of the spinal cord at the Th10-12 level and adhesions in the dural sac

RESULTS

The device for our patient (Fig. 4) was made of cast orthocrylic resin with an increased carbon layers including stiffeners to ensure strength and lightness of the construct. The weight of the device was 3050 grams.

Prepregs with reinforcing materials based on carbon, glass, natural and synthetic (aramid, lavsan, nylon) fibers are used in the production of orthoses [18, 19]. Various modifications of epoxy resins are used for binders to allow molding and polymerization of a composite material at sufficiently low temperatures (120–130 °C) and sufficiently low overpressure, under vacuum with greater range of materials including auxiliary ones used for molding products with simplified technology [18]. A high corset was made to keep the torso stable in a vertical position. Spinal deformity correction was not considered at this stage of orthotics. The device was equipped with functional hip joints to allow flexion/extension, abduction and rotation of the hips, double lock hinges for the knee and ankle joints. Medial knee hinges were additionally placed to correct valgus of the lower limbs and femoral and tibial splints of the apparatus were adjusted providing three pressure points and stable standing as shown in Figure 4.

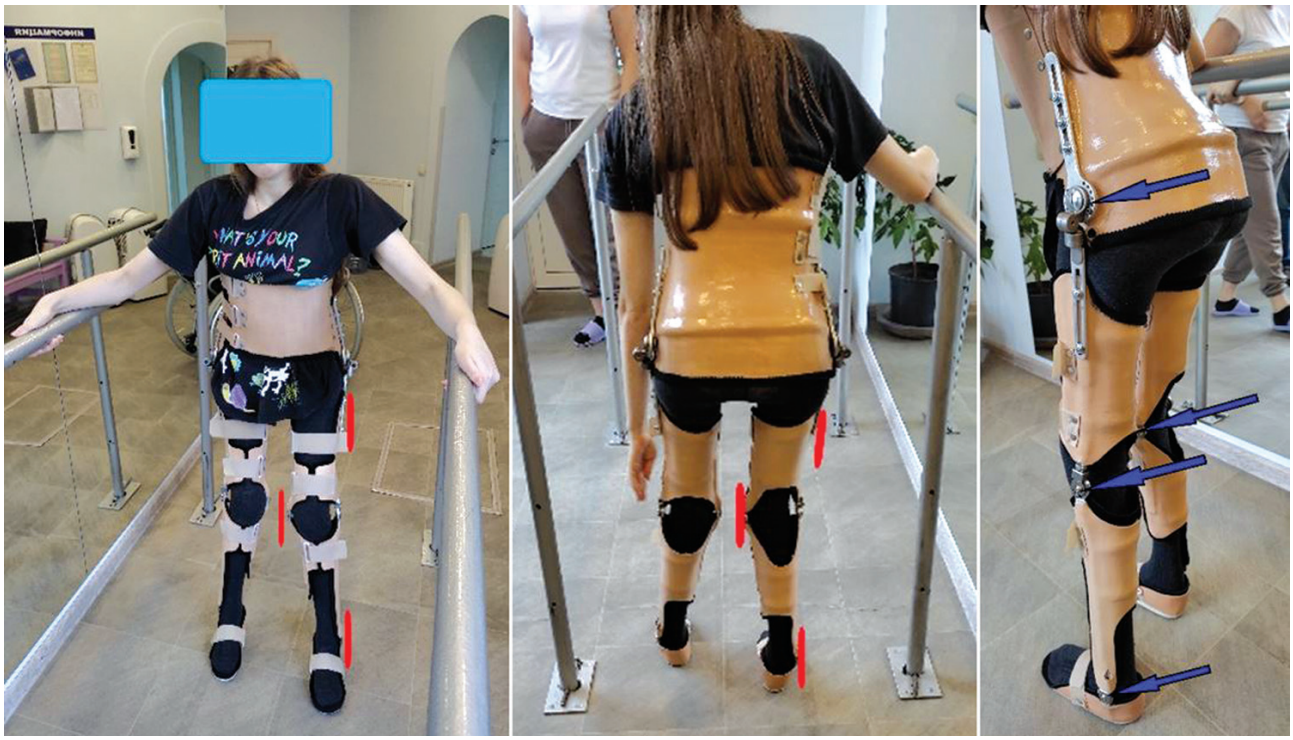

Fig. 4 Photos of patients using devices applied to the body and lower limbs (HKAFO). Pressure points are indicated with red lines. Functional hinges are shown with blue arrows

The device applied to the body and lower limbs (HKAFO) facilitated vertical position and she could ambulate using parallel railings and a walker., locking knee hinges were used to maintain stability during walking with an extension of 180 degrees, and the hip and ankle hinges were functional employed to prevent development of contractures.

The patient showed high compliance with the activities initiated at the center: she took a course of exercise therapy and massage and learned to walk with the device on. She could walk up to 3 meters at the beginning of treatment with the distance increased up to 20 meters at 3 weeks on discharge. No complications were observed with the use of the device. Rehabilitation and the use of an orthosis with a high corset allowed significant reduction in the defense of the paravertebral muscles in the thoracic and lumbar spine. No complications were seen in the patient at an 8-month follow-up with systematic verticalization and walking using the device. A positive result was recorded in the treatment of contractures with the extension increased by 5° in the knee joints and by 10° in the ankle joints on the right and left.

DISCUSSION

The above clinical report demonstrated a patient who had suffered a spinal cord injury resulting in persistent neurological symptoms in the form of flaccid paraplegia with impaired superficial and deep sensitivity and pelvic floor dysfunction. I.N. Novoselova (2021) reported motor and sensory disorders, pelvic floor dysfunction as major clinical manifestations of spinal cord injury [20].

The topography of injuries to the structures of the nervous system can be assessed through impaired sensitivity and motor function, their localization and prevalence [21]. This is due to the anatomical pathways of sensory and motor information [21]. In this case clinical symptoms indicated a complete spinal cord injury involving the anterior and posterior horns that was confirmed by MRI findings of the spinal cord (cystic-glial changes and atrophy of the spinal cord at the Th10-12 level). A.G. Baindurashvili et al. (2015) reported most severe injuries with neurological disorders in children with spinal cord injury localized in the thoracic spine [22].

The patient had poor prognosis for recovery of the motor and sensory functions in the lower limbs. Flaccid paralysis in comparison with spastic (central) palsy is characterized by more severe functional motor impairment combined with sensory and trophic disorders. Motor recovery is the main task in the rehabilitation of patients with spinal cord injury. The above factors set on our team develop a device for the body and the limbs. The HKAFO manufactured at the Center was intended for unloading, replacement and fixation. The device was light and strong due to greater use of carbon layers, equipped with functional hinges to prevent development of contractures, had a high corset for external stabilization of the body and double knee splint for safe standing.

CONCLUSION

The clinical instance demonstrated successful use of orthotics to allow verticalization and gait with the support in a patient with paraplegia and poor prognosis for the recovery of motor functions who could significantly improve her motor activity and psycho-emotional consequences and correct contractures in the catamnesis.

REFERENCES

1. Ivanova G.E., Krylov V.V., Tsykunov M.B., Poliaev B.A., editors. *Reabilitatsiia bolnykh s travmaticheskoi bolezniu spinnogo mozga* [Rehabilitation of patients with traumatic disease of the spinal cord]. M., Moskovskie Uchebniki i Kartolitografiia, 2010, pp. 22-23. (in Russian)
2. Morozov I.N., Mliavykh S.G. Epidemiologiia pozvonochno-spinnomozgovoi travmy (obzor) [Epidemiology of spinal cord injury (review)]. *Meditsinskii Almanakh*, 2011, no. 4, pp. 157-159. (in Russian)
3. Tolkachev V.S., Bazhanov S.P., Ulianov V.Iu., Fedonnikov A.S., Ninel V.G., Salikhu Kh., Norkin I.A. Epidemiologiia travm pozvonochnika i spinnogo mozga (obzor) [Epidemiology of injuries of the spine and spinal cord (review)]. *Saratovskii Nauchno-meditsinskii Zhurnal*, 2018, vol. 14, no. 3, pp. 592-595. (in Russian)
4. Mironov S.P., editor. *Travmatizm, ortopedicheskaia zabolevaemost, sostoianie travmatologo-ortopedicheskoi pomoshchi naseleniiu Rossii v 2016 godu. Ezhegodnyi sbornik statei* [Injuries, orthopedic morbidity, the state of traumatological and orthopedic care for the population of Russia in 2016. Annual collection of articles]. M., Teler, 2017, 149 p. (in Russian)
5. Zaletina A.V., Vissarionov S.V., Baindurashvili A.G., Kokushin D.N., Soloveva K.S. Povrezhdeniia pozvonochnika i spinnogo mozga u detskogo naseleniia [Injuries of the spine and spinal cord in children]. *Mezhdunarodnyi Zhurnal Prikladnykh i Fundamentalnykh Issledovanii*, 2017, no. 12-1, pp. 69-73. (in Russian)
6. Starodubtsev A.A., compiler. *Travma spinnogo mozga: metodicheskaia razrabotka k prakticheskim zaniatiiam* [Spinal cord injury: a technique manual]. Stavropol, Stavropolskii gos. med. un-t, 2017, 15 p. (in Russian)
7. Krylov V.V., Grin A.A., Lutsik A.A., Parfenov V.E., Dulaev A.K., Manukovskii V.A., Konovalov N.A., Perlmutter O.A., Safin Sh.M., Kravtsov M.N., Manashchuk V.I., Rerikh V.V. Rekomendatelnyi protokol lecheniia ostroi oslozhnennoi i neoslozhnennoi travmy pozvonochnika u vzroslykh (Assotsiatsiia Neirokhirurgov RF). Chast 1 [Recommendation protocol for the treatment of acute complicated and uncomplicated spinal injury in adults (Association of Neurosurgeons of the Russian Federation). Part 1.]. *Voprosy Neirokhirurgii im. N.N. Burdenko*, 2014, vol. 78, no. 6, pp. 60-67. (in Russian)
8. Mironov E.M. Rol ortezirovaniia v kompleksnoi reabilitatsii bolnykh s posledstviiami pozvonochno-spinnomozgovoi travmy [The role of orthotics in the complex rehabilitation of patients with consequences of spinal cord injury]. *Mediko-sotsialnaia Ekspertiza i Reabilitatsiia*, 2012, no. 1, pp. 56-57. (in Russian)
9. Pismennaia E.V., Petrushanskaia K.A., Shapkova E.Iu. Kriterii osvoeniia navykov khodby v ekzoskelete u patsientov s posledstviiami pozvonochno-spinnomozgovoi travmy [Criteria for mastering the skills of walking in the exoskeleton in patients with the consequences of spinal cord injury]. *Rossiiskii Zhurnal Biomekhaniki*, 2018, vol. 22, no. 1, pp. 85-100. (in Russian)
10. Brown-Triolo D.L., Roach M.J., Nelson K., Triolo R.J. Consumer perspectives on mobility: implications for neuroprosthesis design. *J. Rehabil. Res*. Dev., 2002, vol. 39, no. 6, pp. 659-669.
11. Hartigan C., Kandilakis C., Dalley S., Clausen M., Wilson E., Morrison S., Etheridge S., Farris R. Mobility Outcomes Following Five Training Sessions with a Powered Exoskeleton. *Top Spinal Cord Inj. Rehabil*., 2015, vol. 21, no. 2, pp. 93-99. DOI: 10.1310/sci2102-93.
12. Puzin S.N., Shishkin B.V., Lavrova D.I., Volynets G.V., Pirozhkova T.A., Spivak B.G., An A.V., compilers. *Mediko-sotsialnye pokazaniia k obespecheniiu invalidov ortezami: metod. rekomendatsii dlia spetsialistov biuro mediko-sotsialnoi ekspertizy, reabilitatsionnykh uchrezhdenii i protezno-ortopedicheskikh predpriiatii* [Medico-social indications for providing disabled people with orthoses: a technique manual for specialists of the Bureau of Medical and Social Expertise, rehabilitation institutions and prosthetic-and-orthopedic enterprises]. M., Federal State Bureau of Medical and Social Expertise, 2007, pp. 40-41. (in Russian)
13. Healy A., Farmer S., Pandyan A., Chockalingam N. A systematic review of randomised controlled trials assessing effectiveness of prosthetic and orthotic interventions. *PLoS One*, 2018, vol. 13, no. 3, pp. e0192094. DOI: 10.1371/journal.pone.0192094.
14. Nikitin S.E., Pikhlak A.E., Garkavi A.V., Muteva N.A. Rol i mesto ortezoterapii v mediko-sotsialnoi reabilitatsii bolnykh s porazheniem kostno-sustavnoi sistemy [The role and place of orthosis therapy in the medical and social rehabilitation of patients with the osteoarticular system involvement]. *Rossiiskii Meditsinskii Zhurnal*, 2013, no. 6, pp. 44-48. (in Russian)
15. Vinderlikh M.E. Printsipy sovershenstvovaniia pomoshchi pri neiroortopedicheskoi patologii u detei [Principles of improving care for neuroorthopedic pathology in children]. *Vestnik Meditsinskogo Instituta «Reaviz»: reabilitatsiia, vrach i zdorove*, 2020, no. 5, pp. 123-127. (in Russian)
16. Mahoney F.I., Barthel D.W. Functional evaluation: The Barthel Index. *Md. State Med. J*., 1965, vol. 14, pp. 61-65.
17. Hauser S.L., Dawson D.M., Lehrich J.R., Beal M.F., Kevy S.V., Propper R.D., Mills J.A., Weiner H.L. Intensive immunosuppression in progressive multiple sclerosis. A randomized, three-arm study of high-dose intravenous cyclophosphamide, plasma exchange, and ACTH. *N. Engl. J. Med*., 1983, vol. 308, no. 4, pp. 173-180. DOI: 10.1056/NEJM198301273080401.
18. Bulgakov G.N., Nikitin S.E., Onukhov M.S., Petukhova M.L., Saakian A.A. Funktsionalnye vozmozhnosti ortezov iz karbonovykh tkanei [Functionality of orthoses made of carbon fabrics]. *Vestnik Vserossiiskoi Gildii protezistov-ortopedov*, 2010, no. 4 (42), pp. 41-44. (in Russian)
19. Brehm M.A., Beelen A., Doorenbosch C.A., Harlaar J., Nollet F. Effect of carbon-composite knee-ankle-foot orthoses on walking efficiency and gait in former polio patients. *J. Rehabil. Med*., 2007, vol. 39, no. 8, pp. 651-657. DOI: 10.2340/165-1977-0110.
20. Novoselova I.N. *Sistema rannei kompleksnoi reabilitatsii detei s pozvonochno-spinnomozgovoi travmoi. Avtoref. diss. ... kand. med. nauk* [The system of early complex rehabilitation of children with spinal cord injury. Cand. med. sci. diss. abstr.]. M., 2021, 49 p. (in Russian)
21. Grishchenko K.N., Vismont F.I. *Patologicheskaia fiziologiia nervnoi sistemy: ucheb.-metod. posobie* [Pathological physiology of the nervous system: a training-and-methodical manual]. Minsk, Belorusskii gos. med. un-t, 2009, 24 p. (in Russian)

22. Baindurashvili A.G., Solokhina I.Iu., Kokushin D.N., Belianchikov S.M. Analiz vliianiia razlichnykh faktorov na dinamiku nevrologicheskikh narushenii u detei s pozvonochno-spinnomozgovoi travmoi [Analysis of the influence of various factors on the dynamics of neurological disorders in children with spinal cord injury]. *Ortopediia, Travmatologiia i Vosstanovitelnaia Khirurgiia Detskogo Vozrasta*, 2015, vol. 3, no. 4, pp. 12-21. (in Russian)

The article was submitted 27.10.2021; approved after reviewing 01.02.2022; accepted for publication 28.03.2022.

Information about authors:

1. Denis L. Safronov – Candidate of Medical Sciences, d.l.s@rambler.ru;
2. Alexander A. Kolyabin – a.kolyabin@mail.ru;
3. Alexander A. Grischuk – grishuk1004@mail.ru;
4. Anatoly K. Poverinov – 5870239@mail.ru;
5. Marina A. Shongina – marinashongina@yandex.ru;
6. Anna V. Mazaeva – anchik.777@mail.ru;
7. Vitaly R. Ramazanov – vitasik1609@yandex.ru.

Conflict of interest *None.*

Source of funding *The study was conducted without sponsorship.*