DOI: https://doi.org/10.17816/rjpbr641853

Correction of postural impairments in children with relapsing-remitting multiple sclerosis

Margarita A. Borovik[1,2], Olga A. Laisheva[1,2], Elena Yu. Sergeenko[2],
Nikita A. Demin[2], Marina S. Malyugina[2]

[1] Russian Children's Clinical Hospital, Moscow, Russia;
[2] The Russian National Research Medical University named after N.I. Pirogov, Moscow, Russia

ABSTRACT

BACKGROUND: Patients with multiple sclerosis who have multifocal lesions of the central nervous system may present various complaints, including loss of balance. Some postural control disorders are detected already at an early stage of the disease. Solving this problem is critical, as it directly causes falls with subsequent injuries and deteriorating quality of life. The Balance Evaluation Systems Test offers benefits over other postural control assessment tests. It enables more personalized therapy, especially in the context of decreased tolerance to physical exercise in patients.

AIM: To implement the Balance Evaluation Systems Test for a detailed assessment of postural control, identifying the markers to be used for the development of individual physical rehabilitation programs, as well as to assess the effectiveness of this approach.

MATERIALS AND METHODS: This single-center, prospective, continuous, controlled, randomized study involved 38 patients from the pediatric neuropsychiatric department of a Russian children's clinical hospital (mean age: 13–16 years). All of them had a confirmed diagnosis of relapsing-remitting multiple sclerosis. The patients were examined in the pediatric medical rehabilitation department using the Balance Evaluation Systems Test at the beginning and at the end of a therapeutic exercise course conducted on a daily basis for 10 days. The patients were randomized into two groups, 19 persons each. The control group was offered standard balance exercises; in the experimental group, exercises were selected individually for each patient, considering the identified postural control defects.

RESULTS: The treatment resulted in statistically significant changes for patients both in the control and experimental groups (p <0.001). However, when comparing the results after the exercise course between the groups, the experimental group demonstrated more significant changes in postural control (p <0.001).

CONCLUSION: Therefore, the Balance Evaluation Systems Test helps develop a personalized physical rehabilitation program showing more effective results. This provides patients with an opportunity to improve their functional status and reduce the risk of falls and injuries, while delaying the progression of disability and improving the quality of life.

Keywords: multiple sclerosis; rehabilitation; postural control; balance.

To cite this article:
Borovik MA, Laisheva OA, Sergeenko EYu, Demin NA, Malyugina MS. Correction of postural impairments in children with relapsing-remitting multiple sclerosis. *Russian journal of the physical therapy, balneotherapy and rehabilitation.* 2024;23(4):226–236. DOI: https://doi.org/10.17816/rjpbr641853

Submitted: 17.11.2024 **Accepted:** 27.11.2024 **Published online:** 04.12.2024

DOI: https://doi.org/10.17816/rjpbr641853

Коррекция постуральных нарушений у детей с ремиттирующим рассеянным склерозом

М.А. Боровик[1,2], О.А. Лайшева[1,2], Е.Ю. Сергеенко[2], Н.А. Дёмин[2], М.С. Малюгина[2]

[1] Российская детская клиническая больница, Москва, Россия;
[2] Российский национальный исследовательский медицинский университет им. Н.И. Пирогова, Москва, Россия

АННОТАЦИЯ

Обоснование. Многоочаговое поражение центральной нервной системы при рассеянном склерозе вызывает у пациентов разные жалобы, одна из которых — нарушение равновесия. Уже на ранней стадии заболевания выявляются те или иные расстройства постурального контроля. Решение этой проблемы имеет важное значение, так как её прямое следствие — падения с последующей травматизацией и ухудшением качества жизни. Преимущество перед другими оценочными тестами постурального контроля имеет Balance Evaluation Systems Test. С его помощью терапия проводится более персонифицировано, особенно в условиях снижения толерантности к физической нагрузке у пациентов.

Цель исследования — внедрение Balance Evaluation Systems Test для детальной оценки постурального контроля, выявления маркеров, на основании которых происходит составление индивидуальной программы физической реабилитации, а также оценка эффективности данного подхода.

Материалы и методы. Исследование носит характер одноцентрового проспективного сплошного контролируемого рандомизированного. В нём приняли участие 38 пациентов психоневрологического отделения для детей Российской детской клинической больницы, средний возраст которых составлял 13–16 лет. Все имели подтверждённый диагноз ремиттирующего рассеянного склероза. Пациенты прошли диагностику в отделении медицинской реабилитации для детей с помощью Balance Evaluation Systems Test в начале и конце курса лечебной физкультуры, занятия проводились ежедневно в течение 10 дней. Пациенты были рандомно разделены на 2 группы по 19 человек. Контрольная группа получала стандартные упражнения на равновесие, а в экспериментальной упражнения подбирались индивидуально под каждого пациента с учётом выявленного дефицита постурального контроля.

Результаты. В результате лечения пациенты контрольной и экспериментальной группы показали статистически значимые изменения (p <0,001), но при сравнении результатов после проведённого курса между группами более значимые изменения постурального контроля произошли в экспериментальной группе (p <0,001).

Заключение. Таким образом, Balance Evaluation Systems Test позволяет составить персонифицированную программу физической реабилитации, которая показывает более эффективные результаты. Это даёт возможность пациентам улучшить функциональный статус и уменьшает риск падений и травматизации, а также помогает отсрочить нарастание инвалидизации и улучшает качество жизни.

Ключевые слова: рассеянный склероз; реабилитация; постуральный контроль; баланс.

Как цитировать:
Боровик М.А., Лайшева О.А., Сергеенко Е.Ю., Дёмин Н.А., Малюгина М.С. Коррекция постуральных нарушений у детей с ремиттирующим рассеянным склерозом // Физиотерапия, бальнеология и реабилитация. 2024. Т. 23, № 4. С. 226–236. DOI: https://doi.org/10.17816/rjpbr641853

Рукопись получена: 17.11.2024 **Рукопись одобрена:** 27.11.2024 **Опубликована online:** 04.12.2024

DOI: https://doi.org/10.17816/rjpbr641853

儿童复发型多发性硬化症患者的姿势障碍矫正

Margarita A. Borovik[1,2], Olga A. Laisheva[1,2], Elena Yu. Sergeenko[2], Nikita A. Demin[2], Marina S. Malyugina[2]

[1] Russian Children's Clinical Hospital, Moscow, Russia;
[2] The Russian National Research Medical University named after N.I. Pirogov, Moscow, Russia

摘要

背景。多发性硬化症引起的中枢神经系统多灶性病变会导致患者出现多种症状，其中之一是平衡障碍。即使在疾病的早期阶段，也可以发现不同程度的姿势控制问题。解决这些问题至关重要，因为其直接后果是跌倒、创伤以及生活质量下降。与其他姿势控制评估测试相比，平衡评估系统测试（Balance Evaluation Systems Test, BEST）具有明显优势。该测试有助于更个性化地制定治疗方案，尤其是在患者耐受体力活动能力下降的情况下。

研究目的。引入平衡评估系统测试（BEST），用于详细评估姿势控制问题，识别关键指标，以制定个性化的物理康复计划，并评估该方法的有效性。

材料与方法。本研究为单中心、前瞻性、连续性对照随机研究，共有38名年龄在13至16岁之间的患者参与，这些患者来自俄罗斯儿童临床医院的儿童心理神经科病房，并被确诊为复发型多发性硬化症。患者在儿童医学康复科通过BEST测试分别在运动疗法开始前后进行评估。运动训练每天进行一次，持续10天。患者被随机分为两组，每组19人。对照组接受标准平衡训练，而实验组根据每位患者的姿势控制缺陷进行个性化训练。

结果。治疗后，对照组和实验组的患者均显示出统计学上显著的改善（$p<0.001$）。然而，比较两组患者的最终评估结果时，实验组的姿势控制改善更加显著（$p<0.001$）。

结论。平衡评估系统测试（BEST）能够制定更个性化的物理康复方案，且显示出更高的有效性。通过这种方法，患者的功能状态得到改善，跌倒和创伤风险显著降低，同时可以延缓残疾加重的进程，提高生活质量。

关键词：多发性硬化症；康复；姿势控制；平衡。

引用本文:
Borovik MA, Laisheva OA, Sergeenko EYu, Demin NA, Malyugina MS. 儿童复发型多发性硬化症患者的姿势障碍矫正. *Russian journal of the physical therapy, balneotherapy and rehabilitation.* 2024;23(4):226–236. DOI: https://doi.org/10.17816/rjpbr641853

收到: 17.11.2024 **接受:** 27.11.2024 **发布日期：** 04.12.2024

BACKGROUND

One of the key goals of rehabilitation medicine is to improve postural control (PC), or balance, in patients. PC refers to the specific actions undertaken by an individual to maintain, achieve, or restore balance. A person may employ anticipatory, reactive, or combined strategies to achieve PC. In mechanics, balance refers to the state of an object in which the sum of all acting forces equals zero. This property largely depends on the position of the center of gravity relative to the base of support. The ability to maintain equilibrium when the center of gravity is displaced determines the object's stability. Unlike inanimate objects, humans are capable of activating muscles to counteract external forces and prevent falls, thereby exerting control over balance (i.e., postural control). There are three general functional goals in which balance control is involved:

- Maintaining a specific posture
- Executing goal-directed movement into a new position, and
- Maintaining balance when exposed to external forces.

PC is a fundamental motor skill regulated by the central nervous system (CNS) [1].

Balance deficits are among the most common impairments addressed in physical rehabilitation. Multiple sclerosis (MS) is one of the conditions in which this problem is particularly prominent. MS is characterized by multifocal damage to the CNS, resulting in a wide range of clinical manifestations. No other neurological disease presents such a broad coexistence of impairments: weakness, fatigue, spasticity, tremor, ataxia, sensory and visual loss, pain, cognitive dysfunction, depression, and neurogenic organ dysfunction (e.g., neurogenic bladder or bowel). The unpredictable progression of these symptoms complicates the management of patients with MS. Alongside standard pharmacologic therapy, physical exercise has a corrective effect on disability and quality of life. Rehabilitation goals for patients with MS are often ill-defined. Despite the use of disease-modifying therapies, patients typically experience worsening over time.

A common symptom of MS is impaired balance function. PC disturbances are observed in up to 3% of children with MS, whereas cerebellar symptoms overall are present in 11%–28% of cases [2]. Such disturbances often occur at early stages of the disease, even when clinical manifestations are minimal or absent. Studies have shown that, compared with healthy individuals, patients with MS demonstrate significant PC impairments regardless of task complexity or sensory conditions [3]. Contributing factors to impaired PC include ataxia, reduced muscle strength, visual deficits, spasticity, tremor, and increased fatigue. Other studies have reported increased postural sway in quiet standing, delayed responses to center of gravity displacement, and impaired return to stability limits—findings that indicate dysfunction in multiple systems responsible for maintaining PC. A correlation has been described between impaired PC and structural changes in the white and gray matter of the cerebellum, pons, thalamus, supratentorial associative tracts, and brainstem [4]. Damage to the vestibular nuclei—located at the level of the medulla oblongata, pons, and caudal midbrain—alters both afferent and efferent signaling, resulting in centrally mediated vestibular dysfunction [5]. Lesions in the inferior cerebellar peduncle impair reactive PC, whereas those in the superior peduncle affect kinetic components [6].

Impaired PC reduces patients' functional capacity and increases the risk of falls and injury. Falls are among the most serious consequences of gait and balance impairments. A cross-sectional self-report study of 449 individuals with MS revealed that 58% reported one or more falls in the previous 6 months. A single fall was reported by 13% of respondents, whereas 45% experienced multiple falls. Among those who fell, 58% sustained injuries and 19% required medical care. Fall-related injuries included bruises, cuts, or abrasions (54%); tears or sprains (32%); severe pain (28%); fractures (28%); and traumatic brain injuries (3%). Falls most commonly occurred during transitions (e.g., while getting to bed, a chair, or the shower) and during ambulation. Frequent causes of falls included tripping, slipping during walking, fatigue or exhaustion. Other reported factors included haste, not using assistive devices, and sensations of dizziness or disorientation. Falls within the home may necessitate environmental modifications such as the installation of grab bars, adaptive equipment, shower benches, and fall alert systems.

Fall prevention strategies should be tailored to the individual patient by obtaining a detailed medical history and performing an appropriate assessment, including a functional evaluation. Another important symptom that limits the extent of rehabilitation in patients with MS is fatigue. As neurological deficits progressively affect the entire central nervous system, many functions remain feasible but require intense concentration and considerable effort from the patient. Brain reorganization resulting from neuroplasticity allows for the continuation of specific tasks but impairs multitasking ability. Detailed patient testing and assessment of motor function help optimize the rehabilitation process, enabling targeted focus on specific tasks and minimizing energy expenditure.

Over the past decade, several approaches have been developed to improve PC in patients with MS, including gait and functional training, resistance training, and aerobic exercise. A meta-analysis in this field highlights that one of the most important factors in treatment effectiveness is an individualized approach [7].

The Balance Evaluation Systems Test (BESTest), developed by Horak, Wrisley, and Frank, is an example of a balance test involving various tasks. It is based on the concept proposed by Bernstein, in which PC results from the interaction of several systems, and a deficit in any one of them may lead to impaired balance. These systems include:

- the biomechanical system
- limits of stability
- anticipatory postural adjustments (dependent on interaction between motor areas, basal ganglia, and brainstem regions)
- automatic postural responses (mediated through short-, medium-, and long-loop proprioceptive feedback)
- the sensory system (vestibular pathways and temporoparietal cortex), and
- dynamic balance during walking (coordinated activity of locomotor and postural sensorimotor programs in the brainstem).

Cognitive functions, which are mediated by the cerebral cortex, may also influence PC [8]. Understanding the strategies used by the CNS to maintain PC is essential for the systematic analysis of each patient. This test can help identify the causes of PC impairment and improve the effectiveness of therapeutic interventions [9].

Most clinical PC tests are designed to detect balance impairments and predict falls. The categories of the BESTest were selected based on the neurophysiological foundations of PC and offer an advantage over other tests by providing a more detailed understanding of the problems (see Fig. 1) [10]. Other studies have demonstrated the comparability of this test with objective assessment methods, confirming its reliability [11].

AIM

The work aimed to implement the BESTest in rehabilitation practice for children with MS to assess motor deficits, specifically PC function, and to develop a personalized exercise program.

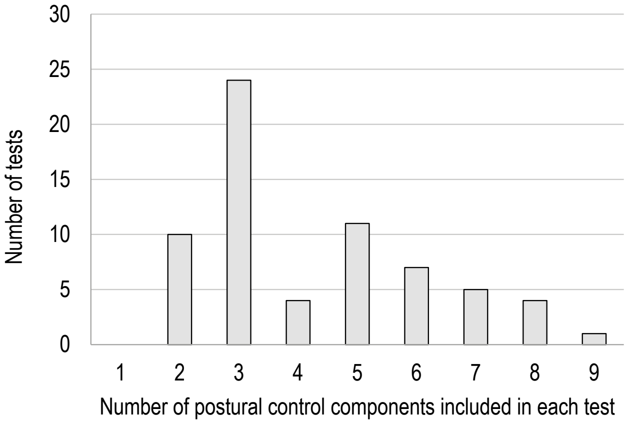

Fig. 1. Evaluation of existing tests covering all components of postural control.

METHODS

Study Design

This was a single-center, prospective, continuous, controlled, randomized study. It included 38 male and female patients under 18 years of age.

Eligibility Criteria

Inclusion criteria:

- Patients with confirmed diagnosis of MS (G35 Multiple sclerosis)
- Age younger than 18 years, and
- Mild disability, defined as an Expanded Disability Status Scale (EDSS) score < 2.5.

Non-inclusion criteria:

- Inability to ambulate independently.

Exclusion criteria:

- Refusal of the patient or legal representative to participate in the study;
- Acute deterioration in the patient's condition.

Study Setting

The study was conducted in the Department of Medical Rehabilitation for Children and the Psychoneurological Department for Older Children at the Russian Children's Clinical Hospital, a branch of the N.I. Pirogov Russian National Research Medical University.

Study Duration

The study was conducted from February through September 2024. The duration of participation for each patient was 2 weeks (10 sessions).

Intervention

Upon admission to the department, patients were assessed for eligibility and signed an informed consent form to participate in the study. They then underwent assessment using the BESTest, which includes 27 tasks, some of which comprise 2 or 4 subitems (e.g., for the right and left sides), totaling 36 items (see Table 1). Each item is rated on a 4-point ordinal scale from 0 (worst performance) to 3 (best performance). Total and section scores are presented as percentages of the maximum possible score. To enhance the reliability of the results, standardized instructions for patients and raters were used, along with stopwatch and ruler measurements.

The therapeutic exercise course consisted of 10 daily sessions, excluding weekends, each lasting 30 minutes. Fatigue levels were monitored in all patients, and exercises were discontinued after 2 forced repetitions. At the end of the course, all patients underwent repeat testing and evaluation of clinical changes.

Study Outcomes

During the study, patients demonstrated improvement in PC, as evidenced both subjectively and by repeated testing at the end of the course.

Table 1. Balance Evaluation Systems Test Structure

Section	Test No.	Test name
Section I		**Biomechanical system**
	1	Base of support
	2	Alignment of the center of mass
	3	Ankle strength and range of motion
	4	Strength of trunk and hip abductors
	5	Sit on the floor and stand up
Section II		**Stability limits**
	6	Sitting verticality and lateral lean
	7	Forward reach
	8	Lateral reach (right and left)
Section III		**Anticipatory postural adjustments**
	9	Sit-to-stand
	10	Rise to toes
	11	Stand on one leg (right and left)
	12	Alternate stair touching
	13	Standing arm raise
Section IV		**Reactive postural response**
	14	In place response—forward
	15	In place response—backward
	16	Compensatory stepping correction—forward
	17	Compensatory stepping correction—backward
	18	Compensatory stepping correction—lateral (right and left)
Section V		**Sensory orientation**
	19	Sensory interaction for balance (modified Clinical Test of Sensory Interaction in Balance [m-CTSIB])
	20	Incline with eyes closed
Section VI		**Gait stability**
	21	Gait on a level surface
	22	Change in gait speed
	23	Head turns while walking
	24	Pivot turns
	25	Step over obstacle
	26	Timed Up and Go
	27	Timed Up and Go with backward counting

Subgroup Analysis

Patients were randomly assigned to a control group (n = 19) and an experimental group (n = 19). The groups were comparable in terms of age and sex. Based on the PC assessment, the control group received a standardized set of balance exercises, whereas the experimental group received personalized exercises tailored to the deficits identified through the BESTest.

Outcomes Registration

The results obtained from the BESTest were recorded and analyzed using SPSS Statistics version 27.0 (IBM, USA).

Ethics Approval

This study complied fully with ethical standards and was approved by the local Ethics Committee of the Russian Children's Clinical Hospital, a branch of the N.I. Pirogov Russian National Research Medical University (protocol excerpt No. 24, October 22, 2024).

Statistical Analysis

Quantitative indicators were assessed for normality using the Shapiro–Wilk test. Quantitative variables with a normal distribution were described using the mean (M), standard deviation (SD), and 95% confidence interval (95% CI). In the absence of a normal distribution, data were presented as the median (Me) and the first and third quartiles (Q1–Q3). Comparisons between two groups for normally distributed variables with equal variances were performed using the Student t-test. Comparison between two groups for a quantitative variable with a non-normal distribution was performed using the Mann–Whitney U test. For comparisons between two related groups with non-normally distributed variables, the Wilcoxon signed rank test was applied. Differences were considered statistically significant at $p < 0.05$.

RESULTS

Participants

Patients had a mild level of disability (EDSS score < 2.5). The median age was 15 years (IQR, 13–16 years); girls predominated over boys (65.8% vs 34.2%). Patients were randomly assigned to the control group (19 participants) and the experimental group (19 participants). The groups were comparable in terms of age and sex.

At baseline, all patients demonstrated impairments in PC. The most pronounced deficits were observed in the biomechanical constraints (Section I), stability limits (Section II), and sensory orientation (Section V), with patients scoring an average of 86.8% in these sections. Additional impairments were noted in reactive postural responses (Section IV) (88.1%), anticipatory postural adjustments (Section III) (88.9%), and gait stability (Section VI) (89.5%) (see Fig. 2).

No statistically significant differences were found between the control and experimental groups at baseline across all sections of the BESTest (Mann–Whitney U test).

Main Study Outcome

Analysis of the experimental group (group I) and the control group (group II) showed no statistically significant differences before the physical therapy (PT) course (p = 0.214). After completion of the PT course, statistically significant differences were identified between the groups ($p < 0.001$), as assessed using the Mann–Whitney U test. Additionally, both groups showed statistically significant improvements in BESTest scores after the intervention ($p < 0.001$), according to the Wilcoxon signed-rank test (see Fig. 3).

A detailed comparison of section scores from the BESTest before and after the PT course was also performed for both groups. No statistically significant differences were observed between the groups in any section before the PT. In each section of the test, participants in both groups demonstrated statistically significant changes. When comparing the post-PT results, statistically significant differences between the groups were identified across all sections (see Table 2).

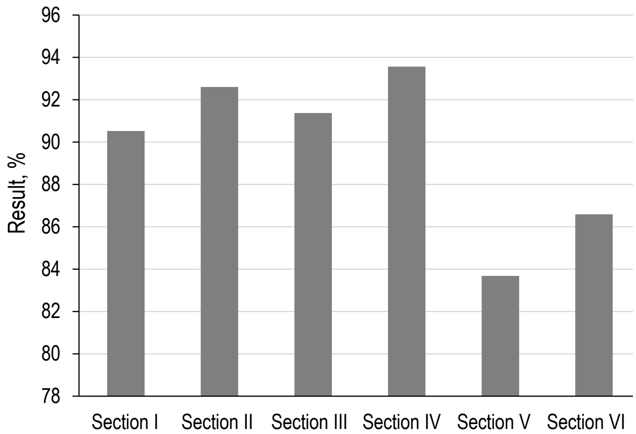

Fig. 2. The average value of test results in children with remitting multiple sclerosis.

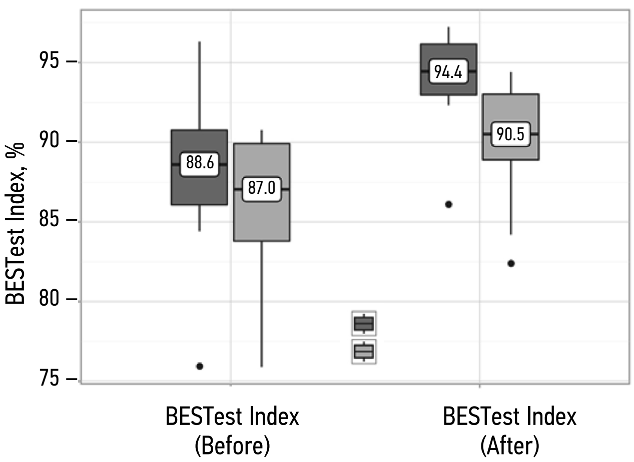

Fig. 3. Analysis of the dynamics of the Balance Evaluation Systems TestIndex depending on the group.

DOI: https://doi.org/10.17816/rjpbr641853

Table 2. Descriptive statistics of quantitative variables depending on the group

Parameter	Group		p
	Group I	Group II	
Section I (before), % Me [IQR]	86.7 [86.0; 93.3]	87.0 [83.0; 93.3]	0.940
Section I (after), % Me [IQR]	97.0 [92.2; 100.0]	93.3 [87.8; 93.7]	0.049
Section II (before), % Me [IQR]	90.5 [85.7; 92.5]	85.7 [82.0; 89.7]	0.158
Section II (after), % Me [IQR]	95.6 [91.5; 100.0]	89.0 [86.6; 90.7]	0.002
Section III (before), % Me [IQR]	88.9 [88.9; 94.4]	88.9 [84.5; 90.1]	0.244
Section III (after), % Me [IQR]	95.2 [93.9; 100.0]	91.6 [88.9; 94.4]	0.003
Section IV (before), % Me [IQR]	90.2 [86.0; 94.4]	88.0 [83.3; 88.9]	0.071
Section IV (after), % Me [IQR]	94.4 [94.2; 100.0]	88.9 [88.6; 94.4]	0.008
Section V (before), % Me [IQR]	86.7 [80.0; 86.7]	82.0 [76.7; 86.7]	0.296
Section V (after), % M (SD)	91.3 (4.6)	85.6 (7.0)	0.005
Section VI (before), % Me [IQR]	90.5 [85.7; 90.5]	85.7 [81.0; 90.5]	0.228
Section VI (after), % Me [IQR]	95.2 [92.3; 97.2]	90.5 [83.3; 91.4]	<0.001

Adverse Events

No adverse events were reported during the study.

DISCUSSION

Summary of Primary Results

This study confirmed the presence of PC impairments in patients with MS even at early stages of the disease. These impairments were identified even in patients who reported no symptoms, consistent with the “clinical-splitting syndrome” described by Markov and Leonovich, which refers to a mismatch between the severity of subjective symptoms and the extent of structural changes [12]. The BESTest enabled detailed assessment of PC, detection of latent functional impairments in this population, and development of an effective individualized physical rehabilitation program.

Interpretation

In our previous study of balance using diagnostic stabilometry, we identified specific alterations in children with MS, including an increased base of support and increased velocity of center of pressure displacement [13]. Other researchers have reported similar findings in adults with MS, including increased sway in static posture, delayed responses to external perturbations, and reduced capacity to recover stability. These findings confirm that MS involves dysfunction in multiple systems responsible for balance control and may be associated with damage to both white and gray matter in the cerebellum, pons, thalamus, and supratentorial associative tracts [4].

The personalized approach allowed for more effective rehabilitation without increasing fatigue. Fatigue remains one of the most prevalent and challenging symptoms in patients with MS. It is attributed to both neuromuscular changes and central mechanisms involving the cerebral cortex, thalamus, and basal ganglia. Sleep disturbances, autonomic dysfunction, and cognitive impairment may also contribute to fatigue [14].

Study Limitations

This study has several limitations, including a small sample size and a short duration of follow-up and inpatient therapy.

CONCLUSION

Thus, this study confirmed the importance of an individualized approach to the management of patients with MS and emphasized the need for initiating rehabilitation as early as possible, given that functional impairments may already be present.

The BESTest proved to be an effective tool for comprehensive assessment of postural control and for personalizing PT programs. Improving PC enhances the quality of life in patients with MS and serves as a preventive strategy against falls and injuries. It may also positively affect fatigue perception and respiratory function [15].

ADDITIONAL INFORMATION

Funding source. This work was not supported by any external sources of funding.

Competing interests. The authors declare that they have no competing interests.

Authors' contribution. All authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work. M.A. Borovik — selection and examination of patients, collection and analysis of literary sources, analysis of the data obtained, writing and editing of the article; O.A. Laisheva — scientific supervisor of the study; E.Y. Sergeenko — curation of the study; N.A. Demin — statistical processing of quantitative and categorical data obtained during the study; M.S. Malyugina — literature review, analysis of the data obtained, writing the article.

ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Источник финансирования. Авторы заявляют об отсутствии внешнего финансирования при проведении исследования и подготовке публикации.

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с проведенным исследованием и публикацией настоящей статьи.

Вклад авторов. Все авторы подтверждают соответствие своего авторства международным критериям ICMJE (все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией). Наибольший вклад распределён следующим образом: М.А. Боровик — отбор и осмотр пациентов, сбор и анализ литературных источников, анализ полученных данных, написание и редактирование текста статьи; О.А. Лайшева — научный руководитель исследования; Е.Ю. Сергеенко — курация исследования; Н.А. Дёмин — статистическая обработка количественных и категориальных данных, полученных в ходе исследования; М.С. Малюгина — обзор литературы, анализ полученных данных, написание статьи.

REFERENCES

1. Pollock AS, Durward BR, Rowe PJ, Paul JP. What is balance? *Clinical rehabilitation*. 2000;14(4):402–406. doi: 10.1191/0269215500cr342oa
2. Malik O, Donnelly E, Barnett M. Multiple sclerosis. A quick reference guide. Moscow: Practical Medicine, 2015. 128 p.
3. Comber L, Sosnoff JJ, Galvin R, Coote S. Postural control deficits in people with Multiple Sclerosis: A systematic review and meta-analysis. *Gait Posture*. 2018;61:445–452. doi: 10.1016/j.gaitpost.2018.02.018
4. Potter K, Anderberg L, Anderson D, et al. Reliability, validity, and responsiveness of the Balance Evaluation Systems Test (BESTest) in individuals with multiple sclerosis. *Physiotherapy*. 2018;104(1):142–148. doi: 10.1016/j.physio.2017.06.001
5. Loyd BJ, Agnew L, Fangman A, et al. Characterizing gaze and postural stability deficits in people with multiple sclerosis. *Multiple Sclerosis and Related Disorders*. 2021;55:03205. doi: 10.1016/j.msard.2021.103205
6. Gera G, Fling BW, Horak FB. Cerebellar White Matter Damage Is Associated With Postural Sway Deficits in People With Multiple Sclerosis. *Archives of Physical Medicine and Rehabilitation*. 2020;101(2):258–264. doi: 10.1016/j.apmr.2019.07.011
7. Corrini C, Gervasoni E, Perini G, et al. Mobility and balance rehabilitation in multiple sclerosis: A systematic review and dose-response meta-analysis. *Multiple Sclerosis and Related Disorders*. 2023;69:104424. doi: 10.1016/j.msard.2022.104424
8. Eken MM, Richards R, Beckerman H, et al. Quantifying muscle fatigue during walking in people with multiple sclerosis. *Clinical Biomechanics*. 2020;72:94–101. doi: 10.1016/j.clinbiomech.2019.11.020
9. Sedaghati P, Asgharzadeh G, Zarei H. Functional Balance Tests for Patients with Multiple Sclerosis: A Review Study. *Caspian Journal of Neurological Sciences*. 2022;8(3)178–187. doi: 10.32598/CJNS.8.30.7
10. Horak FB, Wrisley DM, Frank J. The Balance Evaluation Systems Test (BESTest) to Differentiate Balance Deficits. *Physical therapy*. 2009;89(5):484–498. doi: 10.2522/ptj.20080071
11. Hoseinpour F, Valipour M, Taghadosi H, et al. Validation of the BESTest for Measuring Balance in People with Multiple Sclerosis. *Middle East Journal of Rehabilitation and Health Studies*. 2022;9(3):E122033. doi: 10.5812/mejrh-122033
12. Gusev EI, Konovalova AN, Gekht AB. Neurology. National leadership. Moscow: GEOTAR-Media, 2018. 688 p.
13. Borovik MA, Laisheva OA, Volkova EY, Kovalchuk TS. Characteristic of the functional status of the musculoskeletal system in children with multiple sclerosis. *Physical and Rehabilitation Medicine*. 2024;6(1):59–66. doi: 10.26211/2658-4522-2024-6-1-59-66
14. Swanson CW, Fling BW. Links between Neuroanatomy and Neurophysiology with Turning Performance in People with Multiple Sclerosis. *Sensors*. 2023;23(17):7629. doi: 10.3390/s23177629
15. Sanchez-Ruiz R, de la Plaza San Frutos M, Sosa-Reina MD, et al. Associations between respiratory function, balance, postural control, and fatigue in persons with multiple sclerosis: an observational study. *Frontiers in Public Health*. 2024;12:1332417. doi: 10.3389/fpubh.2024.1332417

СПИСОК ЛИТЕРАТУРЫ

1. Pollock A.S., Durward B.R., Rowe P.J., Paul J.P. What is balance? // Clinical rehabilitation. 2000. Vol. 14, N 4. P. 402–406. doi: 10.1191/0269215500cr342oa
2. Малик О., Доннелли Э., Барнетт М. Рассеянный склероз. Краткий справочник. Москва: Практическая медицина, 2015. 128 с.
3. Comber L., Sosnoff J.J., Galvin R., Coote S. Postural control deficits in people with Multiple Sclerosis: A systematic review and meta-analysis // Gait Posture. 2018. Vol. 61. P. 445–452. doi: 10.1016/j.gaitpost.2018.02.018
4. Potter K., Anderberg L., Anderson D., et al. Reliability, validity, and responsiveness of the Balance Evaluation Systems Test

(BESTest) in individuals with multiple sclerosis // Physiotherapy. 2018. Vol. 104, N 1. P. 142–148. doi: 10.1016/j.physio.2017.06.001

5. Loyd B.J., Agnew L., Fangman A., et al. Characterizing gaze and postural stability deficits in people with multiple sclerosis // Multiple Sclerosis and Related Disorders. 2021. Vol. 55. P. 103205. doi: 10.1016/j.msard.2021.103205

6. Gera G., Fling B.W., Horak F.B. Cerebellar White Matter Damage Is Associated With Postural Sway Deficits in People With Multiple Sclerosis // Archives of Physical Medicine and Rehabilitation. 2020. Vol. 101, N 2. P. 258–264. doi: 10.1016/j.apmr.2019.07.011

7. Corrini C., Gervasoni E., Perini G., et al. Mobility and balance rehabilitation in multiple sclerosis: A systematic review and dose-response meta-analysis // Multiple Sclerosis and Related Disorders. 2023. Vol. 69. P. 104424. doi: 10.1016/j.msard.2022.104424

8. Eken M.M., Richards R., Beckerman H., et al. Quantifying muscle fatigue during walking in people with multiple sclerosis // Clinical Biomechanics. 2020. Vol. 72. P. 94–101. doi: 10.1016/j.clinbiomech.2019.11.020

9. Sedaghati P., Asgharzadeh G., Zarei H. Functional Balance Tests for Patients with Multiple Sclerosis: A Review Study // Caspian Journal of Neurological Sciences. 2022. Vol. 8, N 3. P. 178–187. doi: 10.32598/CJNS.8.30.7

10. Horak F.B., Wrisley D.M., Frank J. The Balance Evaluation Systems Test (BESTest) to Differentiate Balance Deficits // Physical therapy. 2009. Vol. 89, N 5. P. 484–498. doi: 10.2522/ptj.20080071

11. Hoseinpour F., Valipour M., Taghadosi H., et al. Validation of the BESTest for Measuring Balance in People with Multiple Sclerosis // Middle East Journal of Rehabilitation and Health Studies. 2022. Vol. 9, N 3. P. E122033. doi: 10.5812/mejrh-122033

12. Гусев Е.И., Коновалова А.Н., Гехт А.Б. Неврология. Национальное руководство. Москва: ГЭОТАР-Медиа, 2018. 688 с.

13. Боровик М.А., Лайшева О.А., Волкова Э.Ю., Ковальчук Т.С. Особенности функционального статуса опорнодвигательного аппарата у детей с рассеянным склерозом // Физическая и реабилитационная медицина. 2024. Т. 6, № 1. С. 59–66. doi: 10.26211/2658-4522-2024-6-1-59-66

14. Swanson C.W., Fling B.W. Links between Neuroanatomy and Neurophysiology with Turning Performance in People with Multiple Sclerosis // Sensors. 2023. Vol. 23, N 17. P. 7629. doi: 10.3390/s23177629

15. Sanchez-Ruiz R., de la Plaza San Frutos M., Sosa-Reina M.D., et al. Associations between respiratory function, balance, postural control, and fatigue in persons with multiple sclerosis: an observational study // Frontiers in Public Health. 2024. Vol. 12. P. 1332417. doi: 10.3389/fpubh.2024.1332417

AUTHORS' INFO

*** Margrita A. Borovik;**
address: 117 Leninsky Ave, 119571 Moscow, Russia;
ORCID: 0009-0004-9663-4805;
eLibrary SPIN: 6307-8201;
e-mail: a1180@rambler.ru

Olga A. Laisheva, MD, Dr. Sci. (Med.), Professor;
ORCID: 0000-0002-8084-1277;
eLibrary SPIN: 8188-2819;
e-mail: olgalaisheva@mail.ru

Elena Y. Sergeenko, MD, Dr. Sci. (Med.), Professor;
ORCID: 0000-0001-7882-1317;
eLibrary SPIN: 4196-6732;
e-mail: elenarsmu@mail.ru

Nikita A. Demin;
ORCID: 0000-0002-5260-2121;
eLibrary SPIN: 1358-0940;
e-mail: deminnic1@gmail.com

Marina S. Malyugina;
ORCID: 0000-0002-2289-5306;
e-mail: malyugms00@gmail.com

ОБ АВТОРАХ

*** Боровик Маргарита Александровна;**
адрес: Россия, Москва, 119571, Ленинский проспект, д. 117;
ORCID: 0009-0004-9663-4805;
eLibrary SPIN: 6307-8201;
e-mail: a1180@rambler.ru

Лайшева Ольга Арленовна, д-р мед. наук, профессор;
ORCID: 0000-0002-8084-1277;
eLibrary SPIN: 8188-2819;
e-mail: olgalaisheva@mail.ru

Сергеенко Елена Юрьевна, д-р мед. наук, профессор;
ORCID: 0000-0001-7882-1317;
eLibrary SPIN: 4196-6732;
e-mail: elenarsmu@mail.ru

Дёмин Никита Алексеевич;
ORCID: 0000-0002-5260-2121;
eLibrary SPIN: 1358-0940;
e-mail: deminnic1@gmail.com

Малюгина Марина Сергеевна;
ORCID: 0000-0002-2289-5306;
e-mail: malyugms00@gmail.com

* Corresponding author / Автор, ответственный за переписку