

CONTEMPORARY REHABILITATION APPROACHES FOR PATIENTS
WITH SPINOCEREBELLAR ATAXIA TYPE 1:
CURRENT CHALLENGES AND FUTURE PERSPECTIVES
SÚČASNÉ REHABILITAČNÉ PRÍSTUPY PRE PACIENTOV
SO SPINOCEREBELÁRNOU ATAXIOU TYPU 1:
SÚČASNÉ VÝZVY A BUDÚCE PERSPEKTÍVY

DEREKA Tetiana^{1,2*}, SHEIKO Vitalii³

¹ Faculty of Healthcare, Alexander Dubcek University of Trenčín, Trenčín, Slovak republic

² Educational and Scientific Institute of Health, Rehabilitation and Physical Education, National University of Ukraine of Physical Education and Sport, Kyiv, Ukraine

³ Faculty of Chemistry and Biology, Ternopil Volodymyr Hnatiuk National Pedagogical University, Ternopil, Ukraine

* corresponding author / korešpondenčný autor: tetiana.dereka@tuni.sk

ABSTRACT

Background: Spinocerebellar ataxia type 1 (SCA1) is a progressive hereditary neurodegenerative disorder characterized by severe impairments of coordination, balance, and motor control. In the absence of effective pathogenetic treatment, physical and occupational therapy remain key components of patient management.

Aim: To analyze contemporary approaches and identify current challenges in the rehabilitation of patients with SCA1.

Methods: A narrative review and theoretical analysis of scientific literature in the fields of clinical neurology, neurogenetics, and rehabilitation medicine were conducted. Priority was given to systematic reviews, clinical trials, and practice-oriented studies indexed in Scopus and Web of Science.

Results: The analysis revealed that despite the growing variety of rehabilitation methods, their clinical application in SCA1 often remains empirical and poorly standardized. The most promising approaches include balance- and coordination-oriented exercise programs supported by objective assessment tools such as the Berg Balance Scale, Performance-Oriented Mobility Assessment, stabilometry, and biofeedback technologies. Major limitations include heterogeneity of protocols, insufficient dose determination and lack of evaluation of long-term outcomes.

Conclusion: Rehabilitation plays a central role in the management of patients with SCA1. Further clinical studies are required to develop and validate standardized, evidence-based rehabilitation protocols tailored to the severity and type of ataxic manifestations.

Key words: Spinocerebellar ataxia type 1. Cerebellar ataxia. Neurorehabilitation. Balance and coordination training. Postural control. Biofeedback. Virtual reality. Technology-assisted rehabilitation.

ABSTRAKT

Východiská: Spinocerebelárna ataxia typu 1 (SCA1) je progresívne dedičné neurodegeneratívne ochorenie, ktoré sa prejavuje závažným narušením koordinácie, rovnováhy a motorickej kontroly. Vzhľadom na absenciu účinnej patogenetickej liečby zostáva fyzická a pracovná terapia kľúčovou súčasťou starostlivosti o pacientov.

Cieľ: Analyzovať súčasné prístupy a identifikovať aktuálne výzvy vo rehabilitácii pacientov so SCA1.

Metodika: Bola vykonaná naratívna recenzia a teoretická analýza vedeckej literatúry v oblastiach klinickej neurológie, neurogenetiky a rehabilitačnej medicíny. Prioritu mali systematické prehľady, klinické štúdie a prakticky orientované výskumy indexované v databázach Scopus a Web of Science.

Výsledky: Analýza ukázala, že napriek rastúcej rozmanitosti rehabilitačných metód ich klinická aplikácia pri SCA1 často zostáva empirická a málo štandardizovaná. Najperspektívnejšie prístupy zahŕňajú cvičebné programy zamerané na rovnováhu a koordináciu, podporované objektívnymi hodnotiacimi nástrojmi, ako sú Bergova škála rovnováhy (Berg Balance Scale), Performance-Oriented Mobility Assessment, stabilometria a biofeedbackové technológie. Hlavnými obmedzeniami sú heterogenita protokolov, nedostatočné stanovenie dávkovania a nedostatok hodnotenia dlhodobých výsledkov.

Záver: Rehabilitácia zohráva ústrednú úlohu v starostlivosti o pacientov so SCA1. Ďalšie klinické štúdie sú potrebné na vypracovanie a overenie štandardizovaných, na dôkazoch založených rehabilitačných protokolov prispôbených závažnosti a typu ataxických prejavov.

Kľúčové slová: Spinocerebelárna ataxia typu 1. Neurorehabilitácia. Tréning rovnováhy a koordinácie. Posturálna kontrola. Pracovná terapia. Biofeedback. virtuálna realita. Technologicky asistovaná rehabilitácia.

INTRODUCTION

Spinocerebellar ataxia type 1 (SCA1) is a progressive neurodegenerative disorder characterized by cerebellar and extracerebellar involvement, leading to impaired motor coordination, balance deficits, and gait instability. Recent literature has expanded the understanding of the epidemiology and genetic mechanisms underlying spinocerebellar ataxia type 1, as well as potential future therapeutic approaches (Dereka et al., 2025). However, despite advances in disease characterization, evidence-

based rehabilitation strategies aimed at improving postural control and balance remain insufficiently systematized.

The main emphasis in clinical practice is on symptomatic therapy and rehabilitation measures aimed at slowing the progression of symptoms and improving the quality of life of patients.

Pharmacological approaches in hereditary ataxias remain largely symptomatic and demonstrate limited long-term effectiveness. Randomized clinical studies investigating antioxidant therapy have reported only modest clinical benefits without substantial modification of disease progression (Rosenberg, 2020). Recent reviews further emphasize that the management of spinocerebellar ataxias currently relies on multidisciplinary symptomatic care, where neurorehabilitation plays a central role in maintaining functional independence and quality of life (Vinokurov et al., 2026).

In the absence of etiotropic treatment, rehabilitation becomes a key area of medical care for SCA1, providing patients with partial restoration of lost functions, a reduction in the risk of falls, and social adaptation (Synofzik et al., 2014).

An integrated approach using rehabilitation, occupational therapy, biofeedback exercises, and modern balance assessment techniques require scientific justification and clinical validation, which underlines the relevance of this study (Tinetti, 1986; He et al., 2021; Lacorte et al., 2021; Matsugi et al., 2025).

AIM

The aim of the study is to analyze modern approaches and identify current problems associated with the rehabilitation of patients with SCA1, including methods of rehabilitation and occupational therapy.

METHODOLOGY

This study was designed as a structured narrative review focused on contemporary rehabilitation approaches and current challenges in patients with spinocerebellar ataxia type 1 (SCA1). A literature search was conducted in the Scopus, Web of Science, and PubMed databases for publications published between January 2014 and March 2026. The search strategy included combinations of the following keywords: “spinocerebellar ataxia type 1”, “SCA1”, “rehabilitation”, “balance training”, “pos-

tural control”, “coordination training”, “occupational therapy”, “biofeedback”, “stabilometry”, “virtual reality”, and “neurorehabilitation”

The review included peer-reviewed articles published in English that focused on rehabilitation interventions, rehabilitation strategies, balance assessment, motor training, occupational therapy, and technology-assisted rehabilitation in patients with hereditary or degenerative cerebellar ataxias. Attention was paid to systematic reviews, clinical studies, meta-analyses, and evidence-based rehabilitation research (He et al., 2021; Lacorte et al., 2021; Matsugi et al., 2025).

Publications unrelated to rehabilitation management, conference abstracts, non-peer-reviewed materials, and studies with insufficient methodological description were excluded. Preference was given to recent publications reflecting contemporary rehabilitation concepts and modern technological approaches in neurological rehabilitation (Bando et al., 2024, 2025; Matsugi et al., 2025).

Older foundational references were retained only when describing standardized clinical assessment tools that remain widely used in neurological rehabilitation practice, including the Berg Balance Scale and the Performance-Oriented Mobility Assessment.

The selected literature was analyzed and synthesized according to the following thematic domains: assessment of balance and motor impairment; differentiation of ataxic manifestations; rehabilitation intervention strategies; occupational therapy approaches; technology-assisted rehabilitation methods; monitoring of rehabilitation outcomes; current limitations and gaps in protocol standardization.

The synthesis of findings focused on identifying commonly used rehabilitation approaches, contemporary technological solutions, rehabilitation goals, and unresolved challenges associated with the clinical management of patients with SCA1. Due to the limited number of rehabilitation studies specifically targeting SCA1, evidence from broader populations with hereditary and degenerative cerebellar ataxias was also considered where clinically relevant.

The methodological approach was aimed at providing an evidence-informed overview of current rehabilitation practices and future directions in the rehabilitation of patients with SCA1.

The initial database search identified 28 relevant publications. After screening according to the inclu-

sion criteria and removal of duplicates, 21 publications focusing on rehabilitation approaches in hereditary and degenerative cerebellar ataxias were included in the final narrative synthesis.

RESULTS

The reviewed literature demonstrates that rehabilitation in patients with spinocerebellar ataxia type 1 follows a structured clinical sequence, including functional assessment, differentiation of ataxic manifestations, and targeted intervention planning.

Baseline assessment of balance and motor function

Effective rehabilitation of patients with SCA1 begins with a comprehensive assessment of motor performance and balance control. Literature data emphasize that baseline evaluation is a prerequisite for individualized rehabilitation planning and outcome monitoring. Clinical assessment commonly includes static and dynamic balance tests, such as the Romberg test and its modifications (Nieschalk et al., 1995; Gras et al., 2017), as well as standardized functional scales, including the Berg Balance Scale (BBS) (Berg, 1989), Performance-Oriented Mobility Assessment (POMA) (Tinetti, 1986), Standing Balance Test, and Sitting Balance Score (Lee et al., 2010).

In recent years, instrumental methods have gained increasing importance. Stabilometric and three-dimensional postural sway analyses provide objective quantitative data on balance impairments, postural control strategies, and compensatory mechanisms (Saunders et al., 2015; Atamaniuk et al., 2016). These tools allow clinicians to identify subtle changes in balance regulation that may not be detected by clinical scales alone and to track rehabilitation-related dynamics over time.

Differentiation of ataxic manifestations

Based on the results of the initial assessment, patients with SCA1 can be functionally classified according to the predominant type of ataxic impairment. Clinical practice distinguishes between static ataxia, characterized by impaired balance in standing and sitting positions, and dynamic ataxia, manifested primarily by gait instability and impaired coordination during movement. In addition, vestibular and cerebellar components of ataxia may coexist to varying degrees (Chien et al., 2022).

According to clinical manifestations, a distinction is made between static ataxia – loss of balance when standing, and dynamic (locomotor) ataxia – loss of coordination during movement. Before starting rehabilitation of patients with SCA1, a thorough assessment of vestibular function is recommended to determine the degree of impairment of coordination and balance.

This functional differentiation is essential for selecting appropriate rehabilitation strategies, as interventions aimed at improving postural stability differ from those targeting limb coordination and gait control. The proposed algorithm for managing ataxic disorders reflects this approach and supports structured decision-making in rehabilitation planning (He et al., 2021; Matsugi et al., 2025).

The reviewed literature allowed the authors to systematize the main domains of rehabilitation management in patients with SCA1. Based on the synthesis of contemporary evidence, a structured rehabilitation framework integrating assessment, therapeutic goals, and modern rehabilitation approaches is proposed in Table 1.

The proposed framework reflects the multidimensional and individualized nature of rehabilitation in SCA1 and emphasizes the growing role of technology-assisted rehabilitation strategies in contemporary neurological practice.

Rehabilitation goals and objectives

Rehabilitation goals in patients with SCA1 are formulated based on the type and severity of motor impairments, disease progression, and individual functional limitations. The primary objectives include improving balance and coordination, reducing the risk of falls, maintaining or enhancing mobility, and supporting independence in activities of daily living (Lacorte et al., 2021; Kotsiubynskyi et al., 2017). Secondary goals focus on preserving physical conditioning, preventing secondary complications such as contractures and muscle atrophy, and promoting social participation and quality of life (Weber et al., 2024).

Given the progressive nature of SCA1, rehabilitation goals are dynamic and require regular reassessment and adjustment throughout the disease course (Synofzik et al., 2014; Bando et al., 2025).

Rehabilitation strategies and interventions

Contemporary studies supported by established

Table 1 Proposed structured rehabilitation framework for patients with spinocerebellar ataxia type 1

Clinical domain	Main impairments	Recommended assessment methods	Rehabilitation goals	Contemporary rehabilitation approaches
Postural stability and balance	Postural sway, impaired standing balance, fall risk	Berg Balance Scale, stabilometry, Romberg test, posturography	Improve static and dynamic balance, reduce fall risk	Balance-oriented exercises, proprioceptive training, stabilometric biofeedback, VR-based balance training
Gait and mobility	Gait instability, reduced gait symmetry, impaired walking endurance	POMA, gait analysis, wearable motion sensors	Improve gait coordination, walking safety, and mobility	Treadmill training, task-oriented gait training, body-weight support systems
Limb coordination and motor control	Dysmetria, tremors, impaired movement precision	Coordination tests, sensor-based motion analysis	Improve movement accuracy and motor coordination	Coordination exercises, repetitive motor training, sensor-based feedback training
Functional independence and ADL	Difficulties in self-care and daily activities	Occupational therapy assessment, functional independence scales	Maintain independence in activities of daily living	Occupational therapy, adaptive devices, task-specific training
Technology-assisted rehabilitation	Reduced motor learning efficiency and monitoring precision	Digital monitoring systems, wearable sensors	Enhance motor learning and individualized rehabilitation	Biofeedback systems, virtual reality, mixed reality, tele-rehabilitation
Long-term rehabilitation management	Progressive functional decline	Repeated functional assessment and longitudinal monitoring	Maintain long-term functional capacity and quality of life	Home-based rehabilitation, supervised exercise programs, individualized long-term rehabilitation planning

rehabilitation concepts indicate that the most effective rehabilitation approaches in SCA1 are based on balance- and coordination-oriented training (He et al., 2021; Ilg et al., 2009; Keller et al., 2014; Synofzik et al., 2014). These interventions aim to enhance sensorimotor integration, improve postural control, and optimize compensatory strategies (Jarbi et al., 2022; Franzò et al., 2024; Matsugi et al., 2025). Core elements include static and dynamic balance exercises, gait re-education, coordination training for the upper and lower limbs, and proprioceptive stimulation.

Rehabilitation programs often incorporate modulation of sensory input through visual fixation, eye-head coordination exercises, and controlled deprivation or enhancement of proprioceptive and vestibular cues. The use of unstable support surfaces and task-specific motor challenges is commonly employed to promote adaptive motor learning and improve postural responses (Ilg et al., 2009; Lacorte et al., 2021). Classes of exercise generally focus on improving precision and accuracy of movements, inter-joint coordination, tremor reduction, and balance during standing and walking (He et al., 2021; Ilg et al., 2009; Jarbi et al., 2022; Lacorte et al., 2021).

Patients with predominantly static ataxia require rehabilitation interventions aimed at improving postural stability, sitting and standing balance, and fall prevention. In contrast, patients with dynamic ataxia benefit primarily from coordination-oriented training focused on gait control, limb coordination, and functional mobility.

Implementation of rehabilitation and occupational therapy

Rehabilitation in patients with SCA1 is typically implemented through structured exercise programs characterized by gradual progression in task complexity, intensity, and motor demands (Keller et al., 2014; Synofzik et al., 2014). Contemporary rehabilitation strategies emphasize regularity, repetition, and individualized adaptation of exercise duration according to the patient's functional capacity and disease severity. Occupational therapy complements rehabilitation interventions by targeting functional activities, upper-limb coordination, fine motor control, and independence in activities of daily living (Lacorte et al., 2021; Kotsiubynskyi et al., 2017).

In recent years, rehabilitation programs have increasingly integrated technology-assisted approaches, including stabilometric platforms, biofeedback systems, wearable sensors, and interactive training devices, which support individualized intervention planning, objective performance monitoring, and patient engagement during therapy (Franzò et al., 2024; Saunders et al., 2015; Jarbi et al., 2022). In addition, home-based rehabilitation and supervised exercise programs may contribute to sustained functional improvement and long-term continuity of care when patient adherence is maintained (Keller et al., 2014; Jarbi et al., 2022).

Technology-assisted rehabilitation in patients with SCA1

Recent advances in neurological rehabilitation increasingly emphasize the integration of technology-assisted rehabilitation approaches in patients with hereditary cerebellar ataxias, including SCA1. Modern rehabilitation technologies aim to improve the precision of assessment, enhance patient engagement, support motor learning, and provide individualized feedback during rehabilitation interventions (Franzò et al., 2024; Lacorte et al., 2021).

One of the most frequently applied approaches involves the use of stabilometric platforms and computerized posturography systems. These technologies enable objective quantification of postural sway, balance asymmetry, and compensatory postural strategies during static and dynamic tasks. Compared with conventional clinical scales alone, stabilometric assessment provides more sensitive detection of subtle balance impairments and allows continuous monitoring of rehabilitation-related changes over time (Saunders et al., 2015; Atamaniuk et al., 2016).

Biofeedback-based rehabilitation has also gained increasing attention in the rehabilitation of cerebellar disorders. Visual, auditory, and vibrotactile feedback systems may enhance sensorimotor integration by providing real-time information about body position, movement accuracy, and postural control. Preliminary studies suggest that biofeedback-assisted balance and coordination training may improve motor performance and increase patient awareness of compensatory movement strategies (Jarbi et al., 2022).

Another emerging direction is the implementation of virtual reality (VR), mixed reality (MR), and interactive gaming technologies in neurological

rehabilitation. These approaches create enriched multisensory environments that promote task-oriented motor training, dynamic balance control, and repetitive practice under motivating conditions. Recent studies indicate that mixed reality-based occupational and rehabilitation programs may improve adherence to rehabilitation, facilitate motor learning, and support functional mobility in patients with cerebellar ataxia (Franzò et al., 2024; Lacorte et al., 2021). Recent meta-analytic evidence also suggests that virtual reality-based rehabilitation interventions may improve balance performance, motor coordination, and overall functional outcomes in patients with ataxic disorders, supporting their growing role in neurorehabilitation practice (Piñar-Lara et al., 2026).

Home-based digital rehabilitation programs and wearable sensor technologies are increasingly explored as tools for long-term rehabilitation management. These systems allow remote monitoring of exercise performance, individualized adjustment of training intensity, and improved continuity of rehabilitation outside specialized clinical centers. Such approaches may be particularly relevant for patients with progressive neurodegenerative disorders requiring prolonged rehabilitation support.

Narrative evidence summarized by Matsugi et al. (2021) further suggests that continuous home-based exercise programs, robotic-assisted rehabilitation, and non-invasive neuromodulation techniques may support motor learning and gait stability in patients with cerebellar ataxia.

Despite promising preliminary findings, the clinical implementation of technology-assisted rehabilitation in SCA1 remains limited by several factors, including high equipment costs, insufficient protocol standardization, limited accessibility in routine neurological practice, and the lack of large-scale longitudinal studies. Further research is required to establish evidence-based recommendations regarding optimal intervention parameters, patient selection, and long-term therapeutic effectiveness.

Monitoring and outcome evaluation

Rehabilitation in SCA1 is a cyclic process that requires continuous monitoring and outcome evaluation. Reassessment using the same clinical scales and instrumental methods applied at baseline allows clinicians to quantify functional changes (Tinetti, 1986), evaluate intervention effectiveness, and modify rehabilitation programs accordingly (Berg,

Table 2 Contemporary rehabilitation approaches in patients with spinocerebellar ataxia type 1: therapeutic targets, modern technologies, reported effects, current limitations, and supporting literature

Rehabilitation approach	Main therapeutic target	Modern technologies/tools	Reported therapeutic effects	Current limitations	Supporting literature
Balance and postural stability training	Improvement of static and dynamic balance, reduction of fall risk	Stabilometric platforms, force platforms, visual biofeedback systems	Improved postural control, increased balance confidence, reduction in sway variability	Lack of standardized balance protocols; variability in assessment methods	Franzò et al., 2024; Jarbi et al., 2022
Gait rehabilitation	Improvement of gait symmetry, coordination, and walking endurance	Treadmill training, body-weight support systems, motion analysis systems	Improved gait speed, step coordination, and functional mobility	Small sample sizes and limited long-term follow-up	Bando et al., 2024; Keller et al., 2014
Coordination and motor control exercises	Enhancement of limb coordination and movement precision	Sensor-based motion tracking, task-oriented motor training devices	Improved upper- and lower-limb coordination and motor accuracy	Heterogeneity of intervention intensity and duration	Synofzik et al., 2014; Matsugi et al., 2025
Intensive multidisciplinary rehabilitation	Maintenance of functional independence and slowing of functional decline	Structured rehabilitation programs with repetitive task-oriented training	Long-term improvement or stabilization of SARA scores and functional performance	Limited availability of specialized neurorehabilitation centers	Bando et al., 2025; Miyai et al., 2012
Occupational therapy interventions	Improvement of activities of daily living and fine motor skills	Adaptive devices, task-specific training, assistive technologies	Increased independence in self-care and daily activities	Insufficient evidence regarding long-term effectiveness	He et al., 2021; Lacorte et al., 2021
Virtual reality (VR)-based rehabilitation	Enhancement of balance, coordination, and patient motivation	Immersive and semi-immersive VR systems, exergaming platforms	Increased patient engagement, improved postural control and motor learning	High equipment costs and limited accessibility	Jarbi et al., 2022; Franzò et al., 2024
Biofeedback-assisted rehabilitation	Optimization of motor performance through sensory feedback	Visual and auditory biofeedback systems	Improved balance reactions and movement correction	Absence of unified clinical implementation guidelines	Franzò et al., 2024
Neuromodulation-assisted rehabilitation	Facilitation of neuroplasticity and motor adaptation	Non-invasive brain stimulation combined with physiotherapy	Potential enhancement of motor learning and balance performance	Limited clinical evidence and lack of standardized protocols	Matsugi et al., 2025
Home-based and tele-rehabilitation programs	Continuity of rehabilitation and increased accessibility	Telemedicine platforms, wearable sensors, remote monitoring systems	Improved adherence to therapy and continuity of exercise programs	Technological barriers and differences in patient digital literacy	Bando et al., 2025; He et al., 2021
Technology-assisted monitoring and assessment	Objective evaluation of disease progression and therapy outcomes	Wearable motion sensors, digital gait analysis, mobile assessment applications	More precise monitoring of functional changes and rehabilitation outcomes	Lack of validated standardized digital assessment systems	Franzò et al., 2024; Matsugi et al., 2025
Future directions in rehabilitation	Development of personalized and standardized rehabilitation strategies	AI-assisted monitoring systems, wearable technologies, digital rehabilitation platforms	Potential improvement in individualized therapy planning and long-term outcome monitoring	Need for validation through large multicenter clinical studies	Bando et al., 2025; Franzò et al., 2024; Matsugi et al., 2025

1989; Saunders et al., 2015; Chien et al., 2022). Improvements are typically observed in balance control, gait stability, and task performance, although the magnitude and duration of effects vary across studies.

Objective monitoring is particularly important in progressive disorders such as SCA1, as it enables timely adjustment of rehabilitation strategies in response to functional decline or changing patient needs (Bando et al., 2025; Ilg et al., 2023).

Recent longitudinal evidence suggests that annual intensive rehabilitation may slow the progression of ataxic symptoms for up to six years in patients with hereditary cerebellar ataxia, although balance deterioration may still progress over time despite continued intervention (Bando et al., 2025).

The analysis of contemporary literature demonstrates that rehabilitation in patients with SCA1 increasingly relies on individualized and technology-assisted approaches aimed at improving balance control, coordination, gait stability and functional independence. Current rehabilitation strategies integrate conventional exercise-based interventions with modern technologies such as stabi-lometric platforms, biofeedback systems, virtual reality, and wearable monitoring devices.

Table 2 summarizes contemporary rehabilitation approaches used in patients with spinocerebellar ataxia, including modern technological tools, reported therapeutic effects, and current limitations identified in recent literature.

As demonstrated in Table 1, modern rehabilitation management in patients with SCA1 extends beyond conventional rehabilitation and increasingly incorporates objective assessment tools and technology-assisted interventions. However, despite promising clinical outcomes, substantial heterogeneity of rehabilitation protocols and limited standardization continue to restrict the comparability and clinical implementation of existing approaches.

Current limitations and gaps

Despite reported benefits of rehabilitation interventions, the analysis reveals significant limitations in current clinical practice. Rehabilitation protocols remain highly heterogeneous with respect to exercise content, intensity, frequency, and duration (He et al., 2021; Matsugi et al., 2025). Outcome measures vary widely across studies, limiting comparability and the formulation of unified clinical

recommendations. Similar methodological limitations were already highlighted in earlier systematic reviews, which reported insufficient standardization of physiotherapy protocols and limited evidence regarding long-term retention of rehabilitation effects in patients with spinocerebellar ataxia (Martins et al., 2013). Furthermore, long-term effects of rehabilitation and optimal dosing strategies remain insufficiently explored (Bando et al., 2024, 2025).

These gaps highlight the need for standardized, evidence-based rehabilitation frameworks and well-designed clinical studies to support their implementation in patients with SCA1.

DISCUSSION

Given the limited efficacy of currently available pharmacological interventions, including antioxidant therapy investigated in hereditary ataxias (Rosenberg, 2020), rehabilitation remains the primary long-term management strategy.

The present analysis highlights the central role of rehabilitation and occupational therapy in the management of patients with SCA1 in the absence of effective disease-modifying therapies (Synofzik et al., 2014; Matsugi et al., 2025). Consistent with contemporary evidence, rehabilitation interventions focusing on balance, coordination, and functional mobility represent the most effective non-pharmacological strategy for preserving functional capacity and quality of life in this patient population (He et al., 2021; Ilg et al., 2009; Weber et al., 2024).

The results of the reviewed studies indicate that structured, balance-oriented rehabilitation programs can lead to measurable improvements in postural control, gait stability, and motor coordination. These findings are in line with recent long-term and intensive rehabilitation studies demonstrating that targeted exercise interventions may partially counteract functional decline associated with progressive cerebellar degeneration. Importantly, the effectiveness of rehabilitation appears to depend on the individualization of programs according to the predominant type of ataxia and the patient's baseline functional status.

Recent longitudinal studies have shown that annual intensive rehabilitation may slow the progression of ataxic symptoms in hereditary cerebellar ataxia over several years (Bando et al., 2025). Nevertheless, balance function continued to deteriorate progressively despite ongoing intervention, indicat-

ing the need for more targeted long-term balance rehabilitation strategies. These findings support the importance of continuous and individualized rehabilitation programs in patients with progressive cerebellar disorders.

Objective assessment and monitoring emerge as critical components of the rehabilitation process. The combined use of standardized clinical scales and instrumental methods, such as stabilometry and biofeedback-based systems, allows for more precise characterization of balance impairments and rehabilitation-related changes. This approach facilitates timely adjustment of intervention strategies and supports a cyclical model of rehabilitation, particularly relevant for progressive neurological disorders such as SCA1 (Saunders et al., 2015; Chien et al., 2022; Ilg et al., 2023).

Contemporary neurorehabilitation increasingly emphasizes individualized and technology-assisted rehabilitation approaches in patients with cerebellar ataxias. The growing integration of stabilometric platforms, biofeedback technologies, wearable motion sensors, virtual and mixed reality systems, and other interactive rehabilitation tools may enhance the precision of rehabilitation interventions, facilitate objective monitoring of motor performance, and support more effective sensorimotor training. In addition to improving balance control, coordination, and gait stability, these technologies may increase patient engagement and adherence to long-term rehabilitation programs. Despite their promising clinical potential and encouraging preliminary outcomes, the routine implementation of technology-assisted rehabilitation remains limited in neurological practice due to insufficient protocol standardization, restricted accessibility, and economic and organizational barriers.

Previous reviews have also emphasized the potential role of high-intensity motor training and exergame-based interventions in degenerative ataxias. According to Lanza et al. (2019), continuous and individually tailored rehabilitation may enhance residual cerebellar circuitry and compensatory neural mechanisms, although rehabilitation effects often decline after training discontinuation.

Despite these encouraging findings, substantial challenges remain. The lack of standardized rehabilitation protocols, variability in exercise dosage and session frequency, and heterogeneity of outcome measures significantly limit the comparability of published results. Furthermore, long-term effects

and optimal training parameters are insufficiently defined, underscoring the need for well-designed clinical studies and consensus-based rehabilitation guidelines (Bando et al., 2024; Matsugi et al., 2025).

Future research should focus on the development and validation of standardized, evidence-based rehabilitation frameworks that integrate rehabilitation, occupational therapy, and modern technological tools. Such frameworks should incorporate clear criteria for patient stratification, goal setting, intervention selection, and outcome evaluation. Addressing these issues will contribute to improving the consistency and clinical applicability of rehabilitation programs for patients with SCA1.

From a clinical perspective, the proposed structured approach may support more consistent rehabilitation planning in neurological practice.

This narrative review has several limitations. The analysis included heterogeneous rehabilitation studies differing in intervention protocols, duration, and outcome measures. Due to the limited number of studies specifically focused on SCA1, evidence from broader cerebellar ataxia populations was also considered. In addition, the narrative design does not allow quantitative comparison of intervention effectiveness. Nevertheless, the review provides an evidence-informed overview of current physiotherapy approaches and emerging technological trends in the rehabilitation of patients with SCA1.

CONCLUSION

Despite significant advances in understanding the genetic and neurophysiological mechanisms of spinocerebellar ataxia type 1, effective disease-modifying treatments remain unavailable. Consequently, symptomatic therapy and rehabilitation constitute the cornerstone of patient management.

Rehabilitation and occupational therapy programs aimed at improving balance, coordination, gait, and functional independence demonstrate considerable potential to mitigate disease-related disability and enhance quality of life (Synofzik et al., 2014; Matsugi et al., 2025; Weber et al., 2024). The integration of balance training, task-specific exercises, and modern technologies such as stabilometry and biofeedback allows for more precise assessment and individualized intervention planning (Saunders et al., 2015; Jarbi et al., 2022; Atamaniuk et al., 2016).

However, the absence of standardized rehabilitation protocols and unified outcome criteria

underscores the need for further clinical research. Future studies should focus on the development, validation, and long-term evaluation of evidence-based rehabilitation programs tailored to the type and severity of ataxic manifestations in patients with SCA1.

REFERENCES

- ATAMANIUK Y., CHYRVA B. *Stabilometriia v nevrolohii ta reabilitatsii*. Kyiv: Medytsyna; 2016. 46 c.
- BANDO K., KONDO Y., ARIAKE Y. et al. Long-Term Effects of Annual Intensive Rehabilitation in Patients with Hereditary Pure Cerebellar Ataxia: A 7-Year Follow-Up Study. *Cerebellum*. 2025; 24 (5): 45-56.
- BANDO K., KONDO Y., MIYAZAKI Y. et al. Differences in the Impact of Intensive Rehabilitation on Hereditary Ataxias and the Cerebellar Subtype of Multiple System Atrophy. *Cerebellum*. 2024; 23 (6): 2447-2456.
- BERG K. Measuring balance in the elderly: Preliminary development of an instrument. *Physiotherapy Canada*. 1989; 44 (6): 304-311.
- DEREKA T., SHEIKO V. Spinocerebellar ataxia type 1: epidemiology, genetics, and future therapeutic prospects. *Zdravotnícke listy*. 2025; 13 (4): 65-73.
- FRANZÒ M., MARINOZZI F., FINTE A. et al. Mixed reality-based smart occupational therapy protocol for cerebellar ataxic patients. *Brain Sciences*. 2024; 14 (10): 1023.
- GRAS L.Z., GANLEY K.J., BOSCH P.R. et al. Use of the Sharpened Romberg as a Screening for Fall Risk: A Pilot Study. *Topics in Geriatric Rehabilitation*. 2017; 33 (2): 113-117.
- HE M., ZHANG H.N., TANG Z.C. et al. Balance and coordination training for patients with genetic degenerative ataxia: a systematic review. *J Neurol*. 2021; 268 (10): 3545-3556.
- CHIEN H.F., ZONTA M.B., CHEN J. Rehabilitation in patients with cerebellar ataxias. *Arquivos de Neuro-Psiquiatria*. 2022; 80 (2): 306-315.
- ILG W., MILNE S., SCHMITZ-HÜBSCH T. et al. Quantitative Gait and Balance Outcomes for Ataxia Trials: Consensus Recommendations. *Cerebellum*. 2023; 22 (6): 1185-1198.
- ILG W., SYNOFZIK M., BRÖTZ D. et al. Intensive coordinative training improves motor performance in degenerative cerebellar disease. *Neurology*. 2009; 73 (22): 1823-1830.
- JARBI S., BUSHART D., KINNAIRD C. et al. Preliminary study of vibrotactile feedback during home-based balance and coordination training in individuals with cerebellar ataxia. *Sensors*. 2022; 22 (9): 3512.
- KELLER J.L., BASTIAN A.J. A home balance exercise program improves walking in people with cerebellar ataxia. *Neurorehabil Neural Repair*. 2014; 28 (8): 770-778.
- KOTSIUBYNSKYI A., SHULHA I. *Reabilitatsiia khvorykh z mozochkovymy syndromamy*. Kyiv: Naukova dumka; 2017. 224 c.
- LACORTE E., BELLOMO G., NUOVO S. et al. The Use of New Mobile and Gaming Technologies for the Assessment and Rehabilitation of People with Ataxia: A Systematic Review and Meta-analysis. *Published in Cerebellum*. 2021; 20 (2): 361-373.
- LANZA G., CASABONA J.A., BELLOMO M. et al. Update on intensive motor training in spinocerebellar ataxia: time to move a step forward? *J Int Med Res*. 2019; 48 (2): 0300060519854626.
- LEE D., BALOH R.W. Sitting balance score and cerebellar dysfunction. *Arch Neurol*. 2010; 67 (5): 557-561.
- MARTINS C.P., RODRIGUES E.C., SANTOS de OLIVEIRA L.A. Physical therapy approach to spinocerebellar ataxia: a systematic review. Abordagem fisioterapêutica da ataxia espinocerebelar: uma revisão sistemática; El abordaje fisioterapêutico de la ataxia espinocerebelosa: una revisión sistemática. *Fisioter Pesq*. 2013; 20 (3): 286-291.
- MATSUGI A., BANDO K., KIKUCHI Y. et al. Rehabilitation for Spinocerebellar Ataxia. *Spinocerebellar Ataxia – Concepts, Particularities and Generalities*. 2021. DOI:10.5772/intechopen.95999
- MATSUGI A., BANDO K., KONDO Y. et al. Effects of Physiotherapy on Degenerative Cerebellar Ataxia: A Systematic Review and Meta-Analysis. *Frontiers in Neurology*. 2025; 15: 1491142.
- NIESCHALK M., DELANK K., STOLL W. Quantitative evaluation of the Romberg test. *Laryngorhinootologie*. 1995; 74 (8): 489-94.
- PIÑAR-LARA M., GONZÁLEZ-CARMONA A., OBRERO-GAITÁN E. et al. The Effectiveness of Virtual Reality-Based Interventions in Patients with Ataxic Conditions: A Systematic



- Review with Meta-Analysis. *Sensors (Basel)*. 2026; 26 (7): 2069.
- ROSENBERG R.N. Antioxidant therapy in hereditary ataxias: a randomized controlled trial. *Neurology*. 2020; 94 (8): e839-e849
- SAUNDERS N.W., KOUTAKIS P., KLOOS A.D. et al. Reliability and validity of a wireless accelerometer for the assessment of postural sway. *J Appl Biomech*. 2015; 31 (3): 159-163.
- SYNOFZIK M., ILG W. Motor training in degenerative spinocerebellar disease: ataxia-specific improvements by intensive physiotherapy and exergames. *Biomed Res Int*. 2014: 2014: 583507.
- TINETTI ME. Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc*. 1986; 34 (2): 119-126.
- VINOKUROV E., MARININA K., BEZPROZVANNY I. Management of spinocerebellar ataxia. *Neurodegenerative Disease Management*. 2026; 30: 1-19.
- WEBER N., BUCHHOLZ M., RÄDKE A. et al. Factors Influencing Health-Related Quality of Life of Patients with Spinocerebellar Ataxia. *Cerebellum*. 2024; 23 (2): 1466-1477.