

Rehabilitation of the lower extremities, standing and walking function in people with spinal cord injury or disease: Guideline of the German-Speaking Medical Society for Spinal Cord Injury

Evidenzbasierte Leitlinie der Deutschsprachigen Medizinischen Gesellschaft für Paraplegiologie zur Rehabilitation der unteren Extremität, der Steh- und Gehfunktion bei Menschen mit Querschnittlähmung

Abstract

Introduction: According of the level and severity of the spinal cord injury or disease (SCI/D), and the impairment of motor, sensory, and autonomic functions, individuals with SCI/D recover some standing and walking capabilities. To increase quality of rehabilitation and use newest evidence, the clinical practice guideline (CPG) “S2e-Guideline Rehabilitation of lower extremities, standing and walking function in people with SCI/D” of the German speaking Medical Association for Paraplegiology (DMGP) was updated.

Methods: Following a multi-tiered approach systematic searches were conducted to identify appropriate literature. For this purpose, the Databases PubMed, EMBASE, Cochrane Library and PEDro were searched. Recommendations on assessments were grouped to the categories “activity and participation” or “body functions/body structures”. Recommendations on interventions were labeled with outcomes standing, walking, strength, range of motion, pain and muscle tonus.

Results: In total, 9,871 studies were identified during the search. Of these, four systematic reviews and eleven primary studies were utilized in composing the recommendations. A total of 25 recommendations were made, with 20 derived from the literature and 5 based on expert consensus. In total 14 functional assessments and 11 rehabilitation interventions became compiled. The assembled recommendations regarding assessments could be well built on published literature, while overall there is a paucity of literature proofing the evidence of specific interventions used in clinical practice. Therefore, the expertise of the international expert group and input from patient representatives were pivotal.

Conclusion: The method of an evidence-based guideline was sufficient for the recommendation of functional assessments but showed the need scientific clarification in the field of clinically established interventions.

Keywords: spinal cord injury, rehabilitation, lower extremities, standing, walking

Zusammenfassung

Einleitung: Je nach Grad oder Ausmaß der Querschnittlähmung (QSL) und den motorischen, sensorischen und autonomen Dysfunktionen können Menschen mit einer QSL Steh- und Gehfähigkeiten entwickeln. Um die Qualität der Rehabilitation zu verbessern und die neuesten Er-

Sophie Irrgang¹
Sandra Himmelhaus¹
Kirstin Allek²
Claudio Bartholet³
Ines Bersch-Porada⁴
Armin Curt³
Burkhardt Huber⁵
Daniel Kuhn⁶
Karen Kynast⁷
Norbert Weidner⁷
Anke Scheel-Sailer^{1,8}

1 Swiss Paraplegic Research, Nottwil, Switzerland

2 Spinal Cord Injury Center, Zentralklinik Bad Berka, Germany

3 Spinal Cord Injury Center, University Hospital Balgrist, Zurich, Switzerland

4 Swiss Paraplegic Center, Nottwil, Switzerland

5 Spinal Cord Injury Rehabilitation Center, Bad Häring, Austria

6 Clinic for Physical and Rehabilitative Medicine, Berufsgenossenschaftliche Kliniken Bergmannstrost, Halle, Germany

7 Spinal Cord Injury Center, Heidelberg University Hospital, Heidelberg, Germany

kenntnisse zu nutzen, wurde die „S2e-Leitlinie Rehabilitation der unteren Extremitäten, Steh- und Gehfunktion bei Menschen mit Querschnittlähmung“ der Deutschsprachigen Medizinischen Gesellschaft für Paraplegiologie (DMGP) aktualisiert.

Methoden: Nach einem mehrstufigen Ansatz wurde eine systematische Suche durchgeführt, um geeignete Literatur zu identifizieren. Zu diesem Zweck wurden die Datenbanken PubMed, EMBASE, Cochrane Library und PEDro durchsucht. Empfehlungen zu Assessments wurden in die Kategorien „Aktivität und Partizipation“ oder „Körperfunktionen/Körperstrukturen“ eingeteilt. Empfehlungen zu Interventionen wurden mit den Ergebnissen Stehen, Gehen, Kraft, Bewegungsumfang, Schmerz und Muskeltonus gekennzeichnet.

Ergebnisse: Insgesamt wurden bei der Suche 9.871 Studien ermittelt. Davon wurden vier systematische Übersichten und elf Primärstudien für die Erstellung der Empfehlungen herangezogen. Es wurden insgesamt 25 Empfehlungen ausgesprochen, von denen 20 aus der Literatur abgeleitet wurden und 5 auf einem Expertenkonsens basierten. Insgesamt wurden 14 Funktionsbewertungen und 11 Rehabilitationsmaßnahmen zusammengestellt. Die zusammengestellten Empfehlungen zu den Beurteilungen konnten sich gut auf die veröffentlichte Literatur stützen, während es insgesamt nur wenig Literatur gibt, die die Evidenz spezifischer, in der klinischen Praxis eingesetzter Interventionen belegt. Daher waren das Fachwissen der internationalen Expertengruppe und die Beiträge der Patientenvertreter von entscheidender Bedeutung.

Schlussfolgerung: Die Methode einer evidenzbasierten Leitlinie war für die Assessments passend, zeigte aber den Bedarf an wissenschaftlicher Klärung im Bereich der klinisch etablierten Interventionen.

Schlüsselwörter: Querschnittlähmung, Rehabilitation, untere Extremitäten, Stehen, Gehen

8 Centre for Rehabilitation and Sport Medicine, Insel Group, University Bern, Switzerland

1 Introduction

A spinal cord injury or disease (SCI/D) can result in motor, sensory, and autonomic dysfunctions, significantly impacting the physical, psychological, and social well-being of affected individuals. The extent of these dysfunctions varies widely, from minimal impairment to complete loss of function below the lesion level. Therefore, depending on the level and severity of the spinal cord lesion, individuals with SCI/D may regain the ability to stand and walk [1], [2]. As a rare health condition, the population-adjusted incidence rate of SCI/D in Germany is 15.727 per million per year [3] and due to the complexity of impairment patterns usually rehabilitation of individuals with a SCI/D is best provided in specialized SCI centers. An evidence-based development of guidelines might help to summarize existing evidence, contextualize the evidence within the cultural framework of the national context and inform clinical practice across the continuum of care with the best recommendation for coordinating and choosing rehabilitation interventions.

The guideline titled “Rehabilitation of the Lower Extremity, Standing, and Walking Function after Spinal Cord Injury” is a first update of the German speaking Society of Paraplegia (DMGP) in the framework of the Association of the Scientific Medical Societies in Germany (AWMF) and provides recommendations for the rehabilitation of

patients with both complete and incomplete SCI/D across acute, subacute, and chronic phases.

The recommendations address the patient’s functional capacity according to the “International Classification of Functioning, Disability and Health” (ICF) [4] and not on the level of lesion or the extent of motor impairment according to the “International Standards for Neurological Classification of Spinal Cord Injury” (ISNCSCI) [5]. Given that rehabilitation is based on the ICF concept, this guideline takes a particular interest in the assessment of functionality and incorporates it into the formulation of recommendations for rehabilitation interventions [6]. This allows for the planning of rehabilitation across the continuum of care.

Primarily, the guideline offers recommendations for adults, though certain recommendations can be adapted for children and adolescents as needed. Although children have different requirements, lesion characteristics and dynamic of recovery the chance to develop a guideline is even less, due to the gap of scientific publications related to the rare health condition [7]. Recognizing that functional changes may occur due to neurological recovery or based on adaptation/compensation [8], the rehabilitation process, including the selection of appropriate assessments and interventions, remains dynamic [9]. The quality of rehabilitation is enhanced through a tailored selection of interventions based on the patient’s needs, common goal formulations [10], [11], and considerations

Table 1: Timetable

Milestone	Date	Topic
1 st digital meeting	30/06/2023	<ul style="list-style-type: none"> • Presentation of the mandate holders • Topicality and relevance of various aspects of version 1 of the guideline • Roadmap and methodological approach • Key questions and search strategy
2 nd digital meeting	30/08/2023	<ul style="list-style-type: none"> • Results of the search and screening for systematic reviews • Structure of the guideline • Sequence and classification of recommendations • Formulation of key questions and recommendations
3 rd digital meeting	15/09/2023	<ul style="list-style-type: none"> • Evidence evaluation and evidence presentation • Sequence and formulation of recommendations for assessments
4 th digital meeting	05/10/2023	<ul style="list-style-type: none"> • Sequence and formulation of recommendations for assessments – results of the evidence assessment and evidence presentation • Supplementary search for primary studies on 2 MWT, 6 MWT, PSFS, FRT/mFRT, Mini-BESTest and SCATS in the period 2015–2023
1 st hybrid meeting	25/10/2023	<ul style="list-style-type: none"> • Formulation and sequence of chapter assessments • Supplementary search for primary studies on TUG, BBS, ADL training, PNF/Bobath/Vojta in the period 2015–2023 and Mini-BESTest, mFRT/FRT in the period <2023 • Search in gray literature: AbilityLab Home and ICORD and SCIRE
5 th digital meeting	10/11/2023	<ul style="list-style-type: none"> • Finalization Chapter Assessments • Evidence on interventions
6 th digital meeting	15/12/2023	<ul style="list-style-type: none"> • Formulation and sequence of chapter interventions • Supplementary search: Primary studies on standing training in the period <2023 and RCTs on decongestive measures and coordinative training
7 th digital meeting	11/01/2024	<ul style="list-style-type: none"> • Confirmation of the guideline in an informal consensus • Supplementary search 10 MWT
Confirmation of the finalized version	29/01/2024	<ul style="list-style-type: none"> • By e-mail
Review in the DMGP guideline commission	15/02/2024–04/2024	<ul style="list-style-type: none"> • By e-mail
Consultation	04/2024–05/2024	<ul style="list-style-type: none"> • By the participating specialist societies and the AWMF
Feedback after the user consensus	06/2024	<ul style="list-style-type: none"> • Adaptation of consensus-based recommendations for interventions
Second revision	05/2024	<ul style="list-style-type: none"> • Revision following feedback from the AWMF

of restoration, neuroplasticity, neuromodulation, and neuroregeneration [12], [13]. Additionally, interventions may be chosen to address or prevent complications in secondary prevention [14].

Although a guideline will provide recommendations for assessments and interventions, the adherence to specific recommendations will depend on the responsible physicians and therapists, taking into account the patient's condition, existing circumstances, and available resources [15], [16]. Because the rehabilitation of the lower extremity follows comparable treatment principles the guidelines are applicable across various care settings, including outpatient care, day-care, inpatient care, rehabilitation, specialized care, and lifelong aftercare for individuals with SCI/D [17]. The recommendations set forth in the guideline are intended for implementation by medical specialists, physiotherapists, and occupational therapists.

The aim of this guideline is to recommend assessments to measure standing or walking function and interventions

to maintain or optimize standing or walking function in individuals with spinal cord injury or disease across the continuum of care.

2 Methods

The methodology applied for the guideline preparation was aligned in the framework of the “AWMF”. The literature search was conducted systematically, similar to the approach used in systematic reviews [15]. The initial methodological analysis of the topic was carried out by two research assistants with therapeutic expertise. This systematic literature search ensured that the guideline was classified as an evidence-based guideline (Se2 guideline). Subsequent to the literature selection, the content was reviewed and refined by a multidisciplinary expert group. The precise timetable is outlined in Table 1. The expert group comprised nine professionals, including physiotherapists, occupational therapists, neurologists,

Table 2: Key questions

No.	Key question
1	Which assessments are reliable and valid in terms of improving the walking/standing function of people with spinal cord injury compared to no assessments or other assessments for people with spinal cord injury/disease?
2	Which therapeutic interventions improve the standing/walking ability of people with spinal cord injury compared to no therapeutic interventions or other therapeutic interventions for people with spinal cord injury/disease?
3	Which assessments are used in studies to measure the effects of interventions on the standing/walking ability of people with spinal cord injury/disease? What effects of therapeutic interventions have been demonstrated in studies?

Table 3: Additional searches

No.	Search topic	Date of search
1	Timed Up and Go Test (TUG)	03/11/2023
2	10-Meter Walking Test (10MWT)	23/01/2024
3	2-Minute Walking Test (2MWT)	11/10/2023
4	6-Minute Walking Test (6MWT)	11/10/2023
5	Berg Balance Scale (BBS)	03/11/2023
6	Mini-BESTest	11/10/2023 / 03/11/2023
7	(Modified) Functional Reach Test (FRT/mFRT)	11/10/2023 / 03/11/2023
8	Penn Spasm Frequency Scale (PSFS)	11/10/2023
9	Spinal Cord Assessment Tool for Spastic Reflexes (SCATS)	11/10/2023
10	ALD-Movement Therapy	07/11/2023
11	PNF, Vojta, Bobath	30/10/2023
12	Coordination training	19/12/2023
13	Standing training	20/12/2023

Table 4: PICO-Framework

Criteria	Description
Population	Adults (≥ 18 years) with spinal cord injury/disease
Interventions	Physiotherapy/occupational therapy and related disciplines: assessments OR interventions
Comparator	No or other assessments OR therapies
Outcomes	Improvement in walking/standing ability with outcomes on functional ability, activity, participation OR reliability and validity

orthopedic surgeons and rehabilitation physicians, delegated from the DMGP.

2.1 Literature search

On March 29, 2023, the databases PubMed, EMBASE, Cochrane Library, and PEDro were searched for systematic reviews published since the completion of Version 1 (2015–2023). The basis for this search were the a priori defined key and research questions (Table 2).

Search terms included text words and subject headings (MeSH). The following MeSH terms were used: “spinal cord injur*”, “paraplegia”, “assistive devices”, “therapeutic interventions”, “assessment”, “muscle strength”, and “walk*”. The search was complemented by screening references of the literature found and the screening of grey literature.

Due to a lack of literature found during the search for systematic reviews, 16 additional searches for primary

literature were conducted in conjunction with the initial search for systematic reviews (Table 3).

These searches targeted studies on specific topics related to interventions or assessments. The basic text words and MeSH terms remained consistent across these searches, with additional terms incorporated to refine and specify the topics of interest.

The comprehensive search strategy for systematic reviews and the searches for primary studies can be found in the Appendix 1 in Attachment 1.

2.2 Eligibility criteria

The eligibility criteria for this literature search were defined according to the PICO-framework [18] and are presented in Table 4.

For all searches, the inclusion criteria were defined as: adults (≥ 18 years) diagnosed with SCI/D, human studies, assessments to quantify the standing and walking func-

tion, functioning assessments, as well as validity, reliability and objectivity, therapeutic interventions to maintain or improve standing and walking function, outcomes on body functioning (strength, mobility, endurance, balance, fine and gross motors skills). Reasons for exclusion were children <18 years), other diseases, animal studies, surgical or pharmacological interventions, biochemical outcomes, other study designs. During the additional searches, these inclusion and exclusion criteria were partially specified and adapted to the specific intervention or assessment.

2.3 Selection process

The selection of retrieved studies was based on pre-defined inclusion criteria. The tool Rayyan was employed to streamline the selection process [19]. Two trained and blinded researchers (SI, SH) independently screened the studies for matching titles, abstracts, and full texts. In cases of ambiguity, an expert (ASS) was consulted to make the final decision on study inclusion or exclusion.

2.4 Analysis of study quality

The quality of the retrieved studies was assessed using the checklists required by the AWMF [15]. The quality of the available literature was evaluated using different tools.

To assess the quality of systematic reviews, the MeaSurement Tool to Assess systematic Reviews 2 (AMSTAR 2) tool was used [20].

To evaluate case-control studies and cross-sectional studies, the Newcastle Ottawa Quality Assessment Scale for Case Control Studies (NOS) was used [21].

Randomized controlled trials (RCTs) were assayed using the Cochrane risk-of-bias tool for randomized controlled trials (RoB 2) tool [22].

Reliability studies were reviewed using the COSMIN Risk of Bias Tool [23].

To finally determine the level of evidence for each included literature, the Oxford Levels of Evidence 2011 were used [24]. Classification is based on a scale of 1 to 5, with the best possible evidence level being represented by a 1.

These evaluations were conducted independently by two blinded reviewers (SI, SH) and subsequently compared. Any discrepancies were resolved through discussion with an expert (ASS).

2.5 Data collection and synthesis of results

An evidence table was created for each PICO question, detailing assessments and interventions (Appendix 2 in Attachment 1). These tables contain information on the references of the included studies, the PICO elements, the main results, and the critical evaluation of the evidence. The assessments were classified into two categories to facilitate a more precise subdivision. The initial

category encompassed assessments pertaining to “activity and participation,” whereas the subsequent category encompassed assessments pertaining to “body functions/body structures.” This categorization is based on the classification system outlined in the ICF model.

To address the third research question, outcomes recorded in the studies were systematically categorized and labeled according to the underlying research question. Outcome labels were assigned to the corresponding recommendation boxes for the interventions, indicating which effects have been explicitly scientifically investigated and validated.

2.6 Formulation of recommendations

Based on the comprehensive literature review, a collaborative exchange was conducted among all participating experts to develop the recommendations. The precise wording and the levels of recommendation were assigned accordingly. The assignment of recommendation levels considered methodologically prepared evidence, clinical experience, relevance and feasibility, consistency of study results, and their applicability to the target patient group and their preferences. Recommendations were categorized as strong (A), standard (B), or open (C). Throughout this process, the expert group systematically evaluated the benefits, side effects, and risks associated with each recommendation.

2.7 Participation of patients

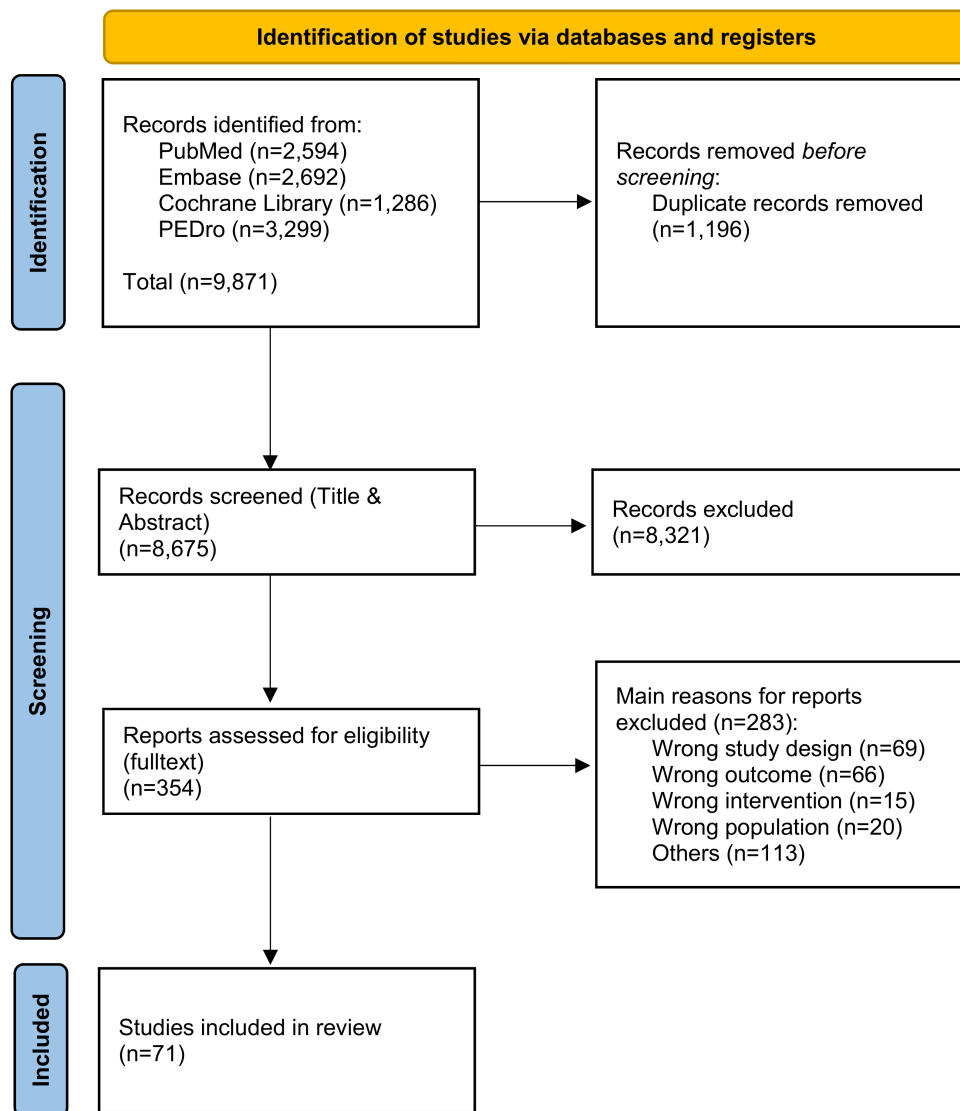
As no patients were involved during the development of the guideline, a focus group discussion was conducted with patient representatives following the guideline’s completion. Patient representatives from Germany and Switzerland participated. This patient group provided various suggestions for modifications to the recommendations, primarily regarding the wording and the levels of recommendation. The expert group reviewed these proposed changes and subsequently incorporated them into the guideline.

3 Results

3.1 Study selection

The comprehensive search for systematic reviews yielded 4,374 articles. Following the screening of titles and abstracts, 285 articles were selected for full-text review, resulting in the inclusion of 49 systematic reviews in the guideline. Additional searches for primary literature produced 5,771 results, of which 59 articles underwent full-text screening. Ultimately, 22 primary studies were included in the guideline.

After expert group revisions, four systematic reviews and eleven primary studies were utilized to address the key questions and formulate the recommendations. An overview of the selection process is presented in Figure 1,



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

Figure 1: PRISMA flow diagram

Adapted from Page et al. [67], licensed under CC BY 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

and detailed flow charts for the individual searches are available in the supplementary material (Appendix 1 in Attachment 1). A total of 25 recommendations were made, with 20 based on the literature and five derived from expert consensus.

3.2 Assessments

Explanation of the recommendations

In this guideline, only assessments that meet psychometric quality requirements (validity, reliability) and align with the guideline's objectives (walking and standing function) were included. The recommendations from the guideline on outcome assessment in primary treatment [25] served as the foundation for content selection. Additionally, as-

sessments used in systematic reviews of interventions to improve walking and standing function were documented. This guideline does not aim to evaluate all assessments used in specific studies or routine clinical practice.

In addition to the listed examinations, assessments, and measurement methods, general principles were described to underline the quality framework: a clinical examination based on medical history, inspection, and palpation is essential for individualized and specific treatment. This includes evaluating reflex status, joint examination (including stability), muscle lengths, depth sensitivity, and pain assessment [26], [27]. Joint status encompasses the range of motion (ROM) and should be performed using the neutral zero method (NNM). The manual muscle function test (MMT) should be conducted regularly, espe-

cially if there is clinical indication of muscle strength changes [28]. The MMT and joint mobility assessments are tailored to the paralysis pattern and the patient's specific situation [29]. Muscle lengths are measured and described using established methods [30]. Leg length should be measured if clinically indicated (e.g., leg length discrepancy) for patients with SCI/D. Pain assessment should follow the recommendations of the guideline on pain in paraplegia [31]. Depth sensitivity is assessed using the tuning fork test (vibration) [26].

The examinations, assessments, and measurement methods are recommended for all phases: acute (up to 2 weeks after SCI/D onset); subacute (3 weeks to 6 months after SCI/D onset or initial treatment/rehabilitation); and chronic (longer than 6 months after SCI/D onset or post-discharge from initial inpatient treatment) [32]. Assessments should be consistently conducted at admission and discharge or at the start and end of outpatient, day-care, or inpatient rehabilitation, during annual reviews, or when there is clinically observed deterioration in functional capacity. Unless otherwise stated, all assessments are applicable to patients with both complete and incomplete SCI/D.

In special cases, additional assessments may be utilized [33]. Consequently, the Spinal Cord Injury Functional Ambulation Inventory (SCI-FAI), previously given a "may" recommendation in the first version of the guideline, is no longer included. Following the overarching rehabilitation objectives, assessments for activities and participation are prioritized, followed by assessments for structure and function.

The recommendations for the assessments are presented in Table 5 and Table 6. They are organized into two categories: recommendations pertaining to the topic of "activity and participation" and recommendations pertaining to the topic of "body functions/body structures."

3.3 Interventions

Explanation of the recommendations

When describing interventions the following five topics evolved as relevant for the individualized adaptation of interventions:

Selection of interventions

The selection of interventions for individuals with SCI/D is influenced by several key aspects:

- The person with SCI/D with their biological, psychological and social circumstances
- The expected complications in the context of SCI/D
- The jointly defined goals in terms of improving functional capacity
- The organizational and structural conditions in the cross-sectional center

Individual with SCI/D: bio-psycho-social considerations

Interventions are tailored to the sensorimotor, neurological, and medical capabilities of the individual, addressing their functional mobility limitations, cognitive impairments, and complications such as pain and spasticity. Additionally, patient-specific factors such as exhaustion and fatigue are integrated into the individualized therapy design.

Anticipated complications in the context of SCI/D

The selection of treatments includes interventions aimed at preventing anticipated complications such as contractures, pain, or fractures.

Jointly defined goals for improving functional capacity

Goals should be collaboratively established with the patient, adhering to the SMART criteria (Specific, Measurable, Achievable, Relevant, Time-bound) [10]. The effectiveness of the intervention should be reassessed after a defined period using appropriate assessments [34]. Corresponding assessments should be conducted at the beginning and end of the therapy phase to evaluate the formulated goals or intermediate goals. Additionally, the guideline on outcome assessment in initial treatment after newly acquired spinal cord injury [25] should be referenced.

From a clinical perspective, interventions can directly or indirectly influence all of these aspects. In the table of recommendations, numbers refer to the specific aspects measured in scientific studies. Furthermore, if necessary, compensation mechanisms and the use of assistive devices are trained and adapted as needed.

Rehabilitation management and organizational aspects

Interventions should be selected by therapists experienced in treating SCI/D in routine clinical practice. Based on regional/focal and/or ADL-related movement therapy, which can be hands-on or hands-off with/without the use of aids, other forms of therapy are supplemented individually or in combination for limited periods, depending on individual goals, expected neurological improvements, and predominant health issues (e.g., spasticity, pain).

In the absence of evidence for individual components within the overall intervention of initial treatment, the institution and therapy team have the responsibility and flexibility to design a goal-oriented and individualized treatment plan.

Even when evidence suggests that increased intensity of active therapies, especially during the acute and subacute phases, associated with better recovery outcomes, lower limb rehabilitation must be integrated into the overall rehabilitation plan, considering other goals and therapeutic interventions, which may require compromises regarding ideal intensity.

Due to the unique situations and special needs of individuals with SCI/D, therapies should be generally conduct-

Table 5: Recommendations for assessments: activity and participation

Recommendation	Evidence	LoR	LoE
The SCIM III should be performed in patients with SCI/D in the acute, subacute and chronic phases as an assessment to describe functional capacity and independence.	Tomaschek [38]	A	1
The WISCI I and II should be performed in patients with SCI/D in the acute, subacute and chronic phases, regardless of walking function.	Tomaschek [38]	A	1
The TUG should be carried out on patients with SCI/D in the acute, subacute and chronic phases as soon as they are able to stand up, walk and turn, possibly with an assistant and/or assistive devices.	Poncumhak [39], van Hedel [40]	A	3
The 10 MWT should be performed on patients with a SCI/D and walking function in the acute, subacute and chronic phases as soon as the patient can walk at least 10 meters.	Van Hedel [40], Amatachaya [41]	A	3
The 2 MWT should be performed in patients with SCI/D in the acute, subacute and chronic phase as soon as patients can walk for two minutes.	Willi [42]	A	3
The 6 MWT should be performed on patients with SCI/D in the acute, subacute and chronic phases as soon as patients can walk for six minutes	Aigner [43]	A	3
In the case of walking ability, the individual risk of falling should be assessed considering other clinical factors. The assessment of the risk of falling should not be carried out in isolation by means of an assessment.	Abou [44]	A	1
The BBS should be performed as soon as patients have some ability to stand and walk to assess balance while walking.	Arora [45], Arsh [46], Jorgensen [47], Lemay [48]	B	1
The Mini-BESTest should be carried out on people with SCI/D who have good walking ability to assess their balance and gait stability.	Chan [45], Roy [46]	B	3
The mFRT should be performed in patients with a SCI/D to assess dynamic balance.	Arora [45], Arsh [46], Arsh [51]	B	1

SCIM: Spinal Cord Independence Measure, SCI/D: Spinal Cord Injury or Disease, WISCI: Walking Index for SCI, TUG: Timed Up and Go, MWT: Meter Walking Test, BBS: Berg Balance Scale, mFRT: modifies Functional Reach Test

Table 6: Recommendations for assessments: body functions/body structures

Recommendation	Evidence	LoR	LoE
The ISNCSCI should be performed as the preferred neurological assessment for patients with SCI/D in the acute, subacute and chronic phases. In children and adolescents with SCI/D, the ISNCSCI should also be performed, but needs to be adapted regarding its implementation and interpretation in the different age groups.	Tomaschek [38]	A	1
The MAS should be used to assess spasticity in patients with SCI/D in the acute, subacute and chronic phases.	Tomaschek [38]	A	1
The PSFS should be used to differentiate between spasms and their frequency as well as for patients with SCI/D in the acute, subacute or chronic phase.	Mills [52]	B	3
The SCATS should be additionally performed for patients with SCI/D in the acute, subacute and chronic phases, in particular to assess the clonic component.	Akpınar [53]	B	3

ISNCSCI: International Standards for Neurological Classification of Spinal Cord Injury, SCI/D: Spinal Cord Injury or Disease, MAS: Modified Ashworth Scale, PSFS: Penn Spasm Frequency Scale, SCATS: Spinal Cord Assessment Tool for Spastic Reflexes

ed as individual sessions. Some interventions may be conducted in a group setting when appropriate.

This scientific approach ensures that interventions are optimally designed to address the complex needs of individuals with SCI/D, enhancing their functional capacity and overall quality of life.

All recommendations for the interventions are displayed in Table 7.

3.4 Outcomes

To address the third key question, all outcomes were systematically categorized and assigned specific labels. The expert group then applied these eight labels to the various identified outcome parameters and matched them with the appropriate recommendations. This process elucidates the quantity and nature of the recommendations that have been subject to scientific investigation and delineates their respective contexts. The majority of recommendations pertain to the outcome category of endurance, while the remaining categories each have two to three corresponding recommendations. Detailed information on all categories and their parameters is presented in Table 8.

Furthermore, these categories can be utilized to establish objectives that the patient can attain throughout the rehabilitation process. The aforementioned categories are not self-contained; thus, they can be utilized as stand-alone entities or in conjunction with one another throughout the course of therapy.

4 Discussion

Although sufficient literature has been identified regarding the assessment of functioning outlined in the recommendations, its quality varies widely, and suffers from significant limitations. Many studies feature small sample sizes, and comparability between studies is lacking.

Regarding rehabilitation interventions, literature was not available for all those utilized in clinical settings. As a result, some recommendations are based on expert consensus. However, a balanced combination of literature-based recommendations and those founded on the expert group's practical experience and expertise was achieved.

The literature included in this guideline lacks specific treatment parameters such as number of repetitions or intensities, making it impossible to provide precise information in the recommendations. The available technical expertise was essential for developing recommendations applicable in everyday practice. The inclusion of patient representatives and the implementation of focus group discussions elevated the recommendation level from B to A for several recommendations for interventions. This highlights the critical importance of incorporating the patient perspective alongside professional expertise and literature-based knowledge.

The descriptions of the functions of walking and standing ability facilitated the presentation and description of assessments and interventions in a structured manner. This structure allows for the interconnection of discrete recommendations, thereby facilitating the formulation of a systematic sequence of assessments and interventions that are pertinent to routine clinical practice. This offers a significant advantage over other guidelines [35], [36], which merely list recommendations for walking and standing function without establishing a connection between them. As previously stated, the guideline can thus increasingly reflect everyday clinical practice, in which assessments and interventions are conducted with similar frequency and the interventions are based on the assessments performed. It is therefore important to view these recommendations as a unified set rather than as individual recommendations.

The following topics have emerged as important research questions for the rehabilitation of standing and walking function in people with SCI/D:

What interventions are used in different cross-sectional centers, e.g. in the acute and subacute phases after SCI/D?

The grid created to categorize assessments and interventions according to the ICF classification can serve as a basis for further observational studies. The aim could be to compare interventions in specific subgroups of people with SCI/D, considering the expected outcome of rehabilitation in different cross-sectional centers, to better understand rehabilitation of standing and walking function, and to develop targeted interventions to improve rehabilitation.

How effective are the consensus-based interventions recommended in this guideline?

All the consensus-based recommendations in this guideline could be a focus for research projects. The overall aim is to be able to base these recommendations on a strong evidence base in the future. This approach will enable continuous improvement in the care of people with SCI/D about their standing and walking function. By integrating evidence-based knowledge, future recommendations can be more precise and effective in improving the quality of life and functional ability of people with SCI/D.

What are the milestones in rehabilitation after the onset of SCI/D? Could they be used to guide the planning of rehabilitation?

Version 1 of this guideline presented a treatment pathway with milestones that had emerged from everyday clinical practice. As there is no evidence to support these milestones, this milestone plan has been dropped. Regarding the comparability of the overall intervention of initial treatment after SCI/D, it may be useful to investigate these milestones scientifically, possibly then subgroup-specific, to structure the treatment pathway and define goals.

Table 7: Recommendations for interventions

Recommendation	Evidence	LoR	LoE
Regional/focal and/or ADL-related movement therapy should be performed both hands-on and hands-off with and without the use of assistive devices in patients with SCI/D in the acute, subacute and chronic phases to maintain and improve muscle strength, mobility and achieve the best possible independence in everyday life.	–	A	EC
Physiotherapy on a neurophysiological basis should be integrated into the entire therapy process for people with SCI/D in all phases to improve tone, pain, joint mobility, coordination and motor learning in people with SCI/D in the acute, subacute and chronic phases.	–	A	EC
The mobilization of the articular structures and muscle stretching should be carried out in a diagnosis-oriented and individually coordinated manner (joint mobility and muscle tone) at the therapeutic intensity required to maintain/improve the joint mobility of people with SCI/D.	–	A	EC
Passive/physical therapy/soft tissue techniques and complex manual decongestive therapy should be carried out in a diagnosis-oriented manner (e.g. soft tissue pain, tension, lymphoedema) to alleviate the symptoms described in people with SCI/D and lay the foundation for functional improvement.	–	A	EC
Exercise therapy in water should be supplemented for people with SCI/D in the subacute and chronic phase if their state of health allows it, it corresponds to the individual objective, other health problems (e.g. spasticity, pain) are in the foreground and there are no contraindications such as incontinence.	Ellapen [54], Li [55]	B	1
Coordination training should be used as a supplement for people with SCI/D in the acute, subacute and chronic phases to maintain/improve coordination and motor learning in people with SCI/D.	Amatachaya [56]	B	3
Exercise trainers with or without FES should be used for people with SCI/D in the acute/subacute and chronic phases, e.g. to reduce spasticity or pain and/or to support neurological recovery and prepare for walking if the neurological prerequisites are met.	Fang [57], van der Scheer [58]	B	1
Standing board/standing table/free-standing bar with or without FES should be used for people with SCI/D in the acute/subacute and chronic phase if standing is possible with the aid adapted to the load limits (circular stability) in order to maintain joint mobility or/and to prepare, maintain/improve the walking/standing function of people with SCI/D and possibly stimulate trunk muscles or enable everyday activities.	Ibitoye [59], Ben [60], Adams [61]	B	3
Gait training should be carried out for people with SCI/D in the acute/subacute and chronic phases with adapted support and weight relief if an improvement in the walking and additional standing function of people with SCI/D is indicated based on the corresponding assessments, or if the neurological requirements are met.	Stampacchia [62], Mehrholtz [63], Gaspar [64]	B	1
Conventional “overground” training of walking function should be performed to maintain/improve the walking/standing function of people with SCI/D in the acute/subacute and chronic phases.	–	B	EC
Medical training therapy, endurance training, personal programs and/or home-based training programs should be professionally guided and adapted to the individual's ability to move and exercise to safely maintain or improve muscle strength in the non-paralyzed, possibly also in the incompletely paralyzed area of people with SCI/D in the subacute and chronic phase, as well as mobility and independence.	Lawrason [65], Quel de Oliveira [66], Gaspar [64]	A	1

ADL: Activity of daily living, SCI/D: Spinal Cord Injury or Disease, EC: expert consensus, FES: Functional electrical stimulation

Table 8: Outcome categories

Outcome category	Outcome parameter	No. of recommendation
Muscle strength	5xSTS, LEMS, Muscle Strength, Muscle Health [56], [57], [58], [65]	3
Muscle tone	PSFS, MAS, SCI-SET, Oral Baclofen Need, Spasticity	2
Mobility	Lower limb mobility, ankle mobility	2
Walking function	SCATS, FIM Motor subscore, 10 MWT, 6 MWT, walking ability, walking speed, gait kinematics, mobility, functional and neurological outcomes [54], [56], [57], [58], [61], [62], [63], [66]	7
Endurance	Energy expenditure, cardiorespiratory function, duration of standing, cardiovascular capacity, VO2 peak, step count outside the training, endurance (6 MWT), aerobic fitness, power output	3
Coordination	TUG, Percentage of Stroop Color and Word Test task errors [56], [57], [62]	2
Quality of life	SF-36, Quality of Life Index for SCI, Satisfaction with Life Scale, Subjective well-being	2
Independence	Functional independence, FIM, SCIM	2

STS: Sit to Stand, PSFS: Penn Spasm Frequency Scale, MAS: Modified Ashworth Scale, SCI-SET: Spinal Cord Injury Spasticity Evaluation Tool, SCATS: SCATS: Spinal Cord Assessment Tool for Spastic Reflexes, FIM: Functional Independence Measure, MWT: Meter/Minute Walking Test, VO2: Maximal Oxygen Uptake, TUG: Timed up and Go, SF-36: Short Form-36, SCIM: Spinal Cord Independence Measure

5 Conclusion

This review underscores the significance of interdisciplinary cooperation in the development of clinical guidelines. The review revealed the existence of literature and studies pertinent to the rehabilitation of SCI/D though the quality of these sources is generally limited. Additionally, the guideline highlights a notable gap in high-quality studies addressing routine interventions, necessitating the inclusion of consensus-based recommendations despite the preference for evidence-based guidelines. To increase the quality of recommendation a S3 guideline including a structured consensus process might be better for future updates of the guideline.

Notes

Guideline

A full version and a comprehensive report in German language was published in the guideline portal of the AWMF [37].

Shared first authorship

Sophie Irrgang and Sandra Himmelhaus share first authorship.

Author contributions

The entire team contributed to the development of the underlying guideline. All authors collaboratively developed and approved the key and research questions. SI and SH were responsible for designing search strategies, screening the identified literature, assessing study quality, and collecting data. In cases of ambiguity, ASS made the

final decision on study inclusion or exclusion. The decision to conduct additional searches for primary literature was made collectively during expert group discussions. SI prepared the initial manuscript draft, which SH and ASS reviewed and provided feedback on. All other authors reviewed and approved the final version of the manuscript.

Funding

Swiss Paraplegic Research, Nottwil, Switzerland, supported the development of the guideline by funding the two research assistants and providing materials and access to databases.

Competing interests

The authors declare that they have no competing interests.

Attachments

Available from <https://doi.org/10.3205/000338>

- 000338_Attachment1.pdf (5328 KB)
Supplementary material

References

- Fehlings MG, Tetreault LA, Wilson JR, Kwon BK, Burns AS, Martin AR, Hawryluk G, Harrop JS. A Clinical Practice Guideline for the Management of Acute Spinal Cord Injury: Introduction, Rationale, and Scope. *Global Spine J*. 2017 Sep;7(3 Suppl):84S-94S. DOI: 10.1177/2192568217703387
- World Health Organisation; The International Spinal Cord Society, editors. *International Perspectives on Spinal Cord Injury*. Geneva: WHO, ISCOS; 2013.

3. Rau Y, Schulz AP, Thietje R, Matrisch L, Frese J, Hirschfeld S. Incidence of spinal cord injuries in Germany. *Eur Spine J*. 2023 Feb;32(2):601-7. DOI: 10.1007/s00586-022-07451-0
4. World Health Organization, editor. International classification of functioning disability and health (ICF). Geneva: WHO; 2001.
5. ASIA and ISCoS International Standards Committee. The 2019 revision of the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI)-What's new? *Spinal Cord*. 2019 Oct;57(10):815-7. DOI: 10.1038/s41393-019-0350-9
6. Meyer T, Kiekens C, Selb M, Posthumus E, Negrini S. Toward a new definition of rehabilitation for research purposes: a comparative analysis of current definitions. *Eur J Phys Rehabil Med*. 2020 Oct;56(5):672-81. DOI: 10.23736/S1973-9087.20.06610-1
7. Mulcahey MJ, Vogel LC, Sheikh M, Arango-Lasprilla JC, Augutis M, Garner E, Hagen EM, Jakeman LB, Kelly E, Martin R, Odenkirchen J, Scheel-Sailer A, Schottler J, Taylor H, Thielen CC, Zebracki K. Recommendations for the National Institute for Neurologic Disorders and Stroke spinal cord injury common data elements for children and youth with SCI. *Spinal Cord*. 2017 Apr;55(4):331-40. DOI: 10.1038/sc.2016.139
8. Hodel J, Sabariego C, Galvis Aparicio M, Scheel-Sailer A, Seijas V, Ehrmann C. Revisiting functioning recovery in persons with spinal cord injury undergoing first rehabilitation: Trajectory and network analysis of a Swiss cohort study. *PLoS One*. 2024 Feb 9;19(2):e0297682. DOI: 10.1371/journal.pone.0297682
9. Harnett A, Bateman EA, McIntyre A, Parikh R, Middleton J, Arora M, Wolfe D, Mehta S. Spinal Cord Injury Rehabilitation Practices. In: Eng JJ, Teasell RW, Miller WC, Wolfe DL, Townson AF, Mortenson WB, Hsieh JTC, Noonan VK, Loh E, Sproule S, McIntyre A, Querée M, editors. *Spinal Cord Injury Rehabilitation Evidence*. SCIRE Professional; 2021. p. 1-126.
10. Lampart P, Häusler F, Langewitz W, Rubinelli S, Sigrist-Nix D, Scheel-Sailer A. Patients' experiences with goal setting during initial rehabilitation after newly acquired spinal cord injury: A pilot qualitative interview study. *J Spinal Cord Med*. 2023 Sep;46(5):837-47. DOI: 10.1080/10790268.2022.2095496
11. Lampart P, Schäppi L, Langewitz WA, Rubinelli S, Sigrist-Nix D, Scheel-Sailer A. Health care professionals' experiences with goal setting during initial rehabilitation after newly acquired spinal cord injury/ disorder - a qualitative focus group study. *Front Rehabil Sci*. 2022 Aug 18;3:982321. DOI: 10.3389/fre.2022.982321
12. Scheel-Sailer A, Post MW, Michel F, Weidmann-Hügler T, Baumann Hölzle R. Patients' views on their decision making during inpatient rehabilitation after newly acquired spinal cord injury-A qualitative interview-based study. *Health Expect*. 2017 Oct;20(5):1133-42. DOI: 10.1111/hex.12559
13. Whalley Hammell K. Experience of rehabilitation following spinal cord injury: a meta-synthesis of qualitative findings. *Spinal Cord*. 2007 Apr;45(4):260-74. DOI: 10.1038/sj.sc.3102034
14. Nas K, Yazmalar L, Şah V, Aydın A, Öneş K. Rehabilitation of spinal cord injuries. *World J Orthop*. 2015 Jan 18;6(1):8-16. DOI: 10.5312/wjo.v6.i1.8
15. Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften (AWMF). AWMF-Regelwerk „Leitlinien“. 2nd ed. Berlin: AWMF; 2020. Available from: <https://www.awmf.org/leitlinien/awmf-regelwerk.html>
16. Brignardello-Petersen R, Carrasco-Labra A, Guyatt GH. How to Interpret and Use a Clinical Practice Guideline or Recommendation: Users' Guides to the Medical Literature. *JAMA*. 2021 Oct 19;326(15):1516-23. DOI: 10.1001/jama.2021.15319
17. Scheel-Sailer A, Selb M, Gmünder HP, Baumberger M, Curt A, Hund-Georgiadis M, Jordan X, Stucki G; Swiss SCI/D Rehabilitation Interest Group. Towards the implementation of clinical quality management at the national level: description of current types of rehabilitation services for spinal cord injury/disorder in Switzerland using an interdisciplinary consensus process. *Eur J Phys Rehabil Med*. 2022 Apr;58(2):190-8. DOI: 10.23736/S1973-9087.21.06923-9.
18. Nishikawa-Pacher A. Research Questions with PICO: A Universal Mnemonic. *Publications*. 2022;10(3):21. DOI: 10.3390/publications10030021
19. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. *Syst Rev*. 2016 Dec 5;5(1):210. DOI: 10.1186/s13643-016-0384-4
20. Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, Moher D, Tugwell P, Welch V, Kristjansson E, Henry DA. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ*. 2017 Sep 21;358:j4008. DOI: 10.1136/bmj.j4008
21. Wells G, Shea B, O'Connell D, Peterson J, Welch V. The Newcastle-Ottawa Scale (NOS) for assessing the quality of case-control studies in meta-analyses. *Eur J Epidemiol*. 2011;25:603-5.
22. Sterne JAC, Savovic J, Page MJ, Elbers RG, Blencowe NS, Boutron I, Cates CJ, Cheng HY, Corbett MS, Eldridge SM, Emberson JR, Hernán MA, Hopewell S, Hróbjartsson A, Junqueira DR, Jüni P, Kirkham JJ, Lasserson T, Li T, McAleenan A, Reeves BC, Shepperd S, Shrier I, Stewart LA, Tilling K, White IR, Whiting PF, Higgins JPT. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*. 2019 Aug 28;366:l4898. DOI: 10.1136/bmj.l4898
23. Mokkink LB, Boers M, van der Vleuten CPM, Bouter LM, Alonso J, Patrick DL, de Vet HCW, Terwee CB. COSMIN Risk of Bias tool to assess the quality of studies on reliability or measurement error of outcome measurement instruments: a Delphi study. *BMC Med Res Methodol*. 2020 Dec 3;20(1):293. DOI: 10.1186/s12874-020-01179-5
24. OCEBM Levels of Evidence Working Group. The Oxford 2011 Levels of Evidence. Oxford: Oxford Centre for Evidence-Based Medicine; 2011.
25. Deutschsprachige Medizinische Gesellschaft für Paraplegiologie e.V., et al. S2e-Leitlinie Ergebniserhebung in der Erstbehandlung nach neu erworbener Querschnittlähmung. Version 1.0. AWMF-Registernummer 179 - 012. Berlin: AWMF; 2020. Available from: <https://register.awmf.org/de/leitlinien/detail/179-012>
26. Masuhr K, Masuhr F, Neumann M. *Neurologie*. 7th ed. Stuttgart, New York: Thieme; 2013. (Duale Reihe).
27. Niethard FU, Pfeil J, Biberthaler P. *Orthopädie und Unfallchirurgie*. 8th ed. Stuttgart: Thieme; 2017. (Duale Reihe).
28. Hislop HJ, Montgomery J, editors. *Manuelle Muskeltests: Untersuchungstechniken nach Daniels und Worthingham*. 8th edl. München, Jena: Elsevier, Urban & Fischer; 2007.
29. Schädler S, Kool J, Lüthi H, Marks D, Oesch P, Pfeiffer A, Wirz M, editors. *Assessments in der Rehabilitation*. 4th ed. Göttingen: Hogrefe; 2019.
30. Smolenski UC, Buchmann J, Beyer L, Harke G, Pahnke J, Seidel W, Janda M. *Manuelle Muskelfunktionsdiagnostik: Theorie und Praxis*. 5th ed. München: Urban & Fischer; 2016.
31. Deutschsprachige Medizinische Gesellschaft für Paraplegiologie e.V., et al. S2k-Leitlinie Schmerzen bei Querschnittlähmung. Version 1.0. AWMF-Registernummer: 179/006. Berlin: AWMF; 2018.
32. EMSCI. Time Schedule: European Multicenter Study about Spinal Cord Injury. 2023. Available from: <https://www.emsci.org/index.php/project/the-project/time-schedule>

33. ;Deutschsprachige Medizinische Gesellschaft für Paraplegiologie e.V., et al. S2e-Leitlinie Verbesserung der Funktionsfähigkeit der oberen Extremität bei zervikaler Querschnittlähmung. AWMF-Registernummer (179-013). Berlin: AWMF; 2020.
34. Steiner WA, Ryser L, Huber E, Uebelhart D, Aeschlimann A, Stucki G. Use of the ICF model as a clinical problem-solving tool in physical therapy and rehabilitation medicine. *Phys Ther*. 2002 Nov;82(11):1098-107.
35. Hornby TG, Reisman DS, Ward IG, Scheets PL, Miller A, Haddad D, Fox EJ, Fritz NE, Hawkins K, Henderson CE, Hendron KL, Holleran CL, Lynskey JE, Walter A; and the Locomotor CPG Appraisal Team. Clinical Practice Guideline to Improve Locomotor Function Following Chronic Stroke, Incomplete Spinal Cord Injury, and Brain Injury. *J Neurol Phys Ther*. 2020 Jan;44(1):49-100. DOI: 10.1097/NPT.0000000000000303
36. Clinicians SCICPL. Clinical Guideline for Standing Adults following Spinal Cord Injury. MASCI; 2019.
37. Deutschsprachige Medizinische Gesellschaft für Paraplegiologie e.V. (DMGP), et al.. S2e-Leitlinie Rehabilitation der unteren Extremität, der Steh- und Gehfunktion bei Menschen mit Querschnittlähmung. Version 2.0. Registernummer 179-009. Berlin: AWMF; 2024. Available from: <https://register.awmf.org/de/leitlinien/detail/179-009>
38. Tomaschek R, Gemperli A, Rupp R, Geng V, Scheel-Sailer A; German-speaking Medical SCI Society (DMGP) Ergebniserhebung Guideline Development Group. A systematic review of outcome measures in initial rehabilitation of individuals with newly acquired spinal cord injury: providing evidence for clinical practice guidelines. *Eur J Phys Rehabil Med*. 2019 Oct;55(5):605-17. DOI: 10.23736/S1973-9087.19.05676-4
39. Poncumhak P, Saengsuwan J, Kamruecha W, Amatachaya S. Reliability and validity of three functional tests in ambulatory patients with spinal cord injury. *Spinal Cord*. 2013 Mar;51(3):214-7. DOI: 10.1038/sc.2012.126
40. van Hedel HJ, Wirz M, Dietz V. Assessing walking ability in subjects with spinal cord injury: validity and reliability of 3 walking tests. *Arch Phys Med Rehabil*. 2005 Feb;86(2):190-6. DOI: 10.1016/j.apmr.2004.02.010
41. Amatachaya S, Naewla S, Srisim K, Arrayawichanon P, Siritaratwat W. Concurrent validity of the 10-meter walk test as compared with the 6-minute walk test in patients with spinal cord injury at various levels of ability. *Spinal Cord*. 2014 Apr;52(4):333-6. DOI: 10.1038/sc.2013.171
42. Willi R, Widmer M, Merz N, Bastiaenen CHG, Zörner B, Bolliger M. Validity and reliability of the 2-minute walk test in individuals with spinal cord injury. *Spinal Cord*. 2023 Jan;61(1):15-21. DOI: 10.1038/s41393-022-00847-1
43. Aigner A, Curt A, Tanadini LG, Maathuis MH. Concurrent validity of single and groups of walking assessments following acute spinal cord injury. *Spinal Cord*. 2017 May;55(5):435-40. DOI: 10.1038/sc.2016.148
44. Abou L, Ilha J, Romanini F, Rice LA. Do clinical balance measures have the ability to predict falls among ambulatory individuals with spinal cord injury? A systematic review and meta-analysis. *Spinal Cord*. 2019 Dec;57(12):1001-13. DOI: 10.1038/s41393-019-0346-5
45. Arora T, Oates A, Lynd K, Musselman KE. Current state of balance assessment during transferring, sitting, standing and walking activities for the spinal cord injured population: A systematic review. *J Spinal Cord Med*. 2020 Jan;43(1):10-23. DOI: 10.1080/10790268.2018.1481692
46. Arsh A, Darain H, Ullah I, Shakil-Ur-Rehman S. Diagnostic tests to assess balance in patients with spinal cord injury: a systematic review of their validity and reliability. *Asian Biomed (Res Rev News)*. 2021 Jun 30;15(3):111-8. DOI: 10.2478/abm-2021-0014
47. Jørgensen V, Opheim A, Halvarsson A, Franzén E, Roaldsen KS. Comparison of the Berg Balance Scale and the Mini-BESTest for Assessing Balance in Ambulatory People With Spinal Cord Injury: Validation Study. *Phys Ther*. 2017 Jun 1;97(6):677-87. DOI: 10.1093/ptj/pzx030
48. Lemay JF, Nadeau S. Standing balance assessment in ASIA D paraplegic and tetraplegic participants: concurrent validity of the Berg Balance Scale. *Spinal Cord*. 2010 Mar;48(3):245-50. DOI: 10.1038/sc.2009.119
49. Chan K, Unger J, Lee JW, Johnston G, Constand M, Masani K, Musselman KE. Quantifying balance control after spinal cord injury: Reliability and validity of the mini-BESTest. *J Spinal Cord Med*. 2019 Oct;42(sup1):141-8. DOI: 10.1080/10790268.2019.1647930
50. Roy A, Higgins J, Nadeau S. Reliability and minimal detectable change of the mini-BESTest in adults with spinal cord injury in a rehabilitation setting. *Physiother Theory Pract*. 2021 Jan;37(1):126-34. DOI: 10.1080/09593985.2019.1622161
51. Arsh A, Darain H, Rahman MU, Ullah I, Shakil-Ur-Rehman S. Reliability of modified functional reach test in the assessment of balance function in people with spinal cord injury: A systematic review. *J Pak Med Assoc*. 2021 Aug;71(8):2040-44. DOI: 10.47391/JPM.1276
52. Mills PB, Vakili AP, Phillips C, Kei L, Kwon BK. Intra-rater and inter-rater reliability of the Penn Spasm Frequency Scale in People with chronic traumatic spinal cord injury. *Spinal Cord*. 2018 Jun;56(6):569-74. DOI: 10.1038/s41393-018-0063-5
53. Akpinar P, Atici A, Ozkan FU, Aktas I, Kulcu DG, Kurt KN. Reliability of the Spinal Cord Assessment Tool for Spastic Reflexes. *Arch Phys Med Rehabil*. 2017 Jun;98(6):1113-8. DOI: 10.1016/j.apmr.2016.09.119
54. Ellapen TJ, Hammill HV, Swanepoel M, Strydom GL. The benefits of hydrotherapy to patients with spinal cord injuries. *Afr J Disabil*. 2018 May 16;7(0):450. DOI: 10.4102/ajod.v7i0.450
55. Li C, Khoo S, Adnan A. Effects of aquatic exercise on physical function and fitness among people with spinal cord injury: A systematic review. *Medicine (Baltimore)*. 2017 Mar;96(11):e6328. DOI: 10.1097/MD.00000000000006328
56. Amatachaya S, Srisim K, Arrayawichanon P, Thaweewannakij T, Amatachaya P. Dual-Task Obstacle Crossing Training Could Immediately Improve Ability to Control a Complex Motor Task and Cognitive Activity in Chronic Ambulatory Individuals With Spinal Cord Injury. *Top Spinal Cord Inj Rehabil*. 2019 Summer;25(3):260-70. DOI: 10.1310/sci18-00038
57. Fang CY, Lien AS, Tsai JL, Yang HC, Chan HL, Chen RS, Chang YJ. The Effect and Dose-Response of Functional Electrical Stimulation Cycling Training on Spasticity in Individuals With Spinal Cord Injury: A Systematic Review With Meta-Analysis. *Front Physiol*. 2021 Nov 19;12:756200. DOI: 10.3389/fphys.2021.756200
58. van der Scheer JW, Goosey-Tolfrey VL, Valentino SE, Davis GM, Ho CH. Functional electrical stimulation cycling exercise after spinal cord injury: a systematic review of health and fitness-related outcomes. *J Neuroeng Rehabil*. 2021 Jun 12;18(1):99. DOI: 10.1186/s12984-021-00882-8
59. Ibitoye MO, Hamzaid NA, Hayashibe M, Hasnan N, Davis GM. Restoring prolonged standing via functional electrical stimulation after spinal cord injury: A systematic review of control strategies. *Biomedical Signal Processing and Control*. 2019;49:34-47. DOI: 10.1016/j.bspc.2018.11.006
60. Ben M, Harvey L, Denis S, Glinsky J, Goehl G, Chee S, Herbert RD. Does 12 weeks of regular standing prevent loss of ankle mobility and bone mineral density in people with recent spinal cord injuries? *Aust J Physiother*. 2005;51(4):251-6. DOI: 10.1016/s0004-9514(05)70006-4

61. Adams MM, Hicks AL. Comparison of the effects of body-weight-supported treadmill training and tilt-table standing on spasticity in individuals with chronic spinal cord injury. *J Spinal Cord Med.* 2011;34(5):488-94. DOI: 10.1179/2045772311Y.0000000028
62. Stampacchia G, Gazzotti V, Olivieri M, Andrenelli E, Bonaiuti D, Calabro RS, Carmignano SM, Cassio A, Fundaro C, Companini I, Mazzoli D, Cerulli S, Chisari C, Colombo V, Dalise S, Mazzoleni D, Melegari C, Merlo A, Boldrini P, Mazzoleni S, Posteraro F, Mazzucchelli M, Benanti P, Castelli E, Draicchio F, Falabella V, Galeri S, Gimigliano F, Grigioni M, Mazzon S, Molteni F, Morone G, Petrarca M, Picelli A, Senatore M, Turchetti G, Bizzarrini E. Gait robot-assisted rehabilitation in persons with spinal cord injury: A scoping review. *NeuroRehabilitation.* 2022;51(4):609-47. DOI: 10.3233/NRE-220061
63. Mehrholz J, Harvey LA, Thomas S, Elsner B. Is body-weight-supported treadmill training or robotic-assisted gait training superior to overground gait training and other forms of physiotherapy in people with spinal cord injury? A systematic review. *Spinal Cord.* 2017 Aug;55(8):722-9. DOI: 10.1038/sc.2017.31
64. Gaspar R, Padula N, Freitas TB, de Oliveira JPJ, Torriani-Pasin C. Physical Exercise for Individuals With Spinal Cord Injury: Systematic Review Based on the International Classification of Functioning, Disability, and Health. *J Sport Rehabil.* 2019 Jul 1;28(5):505-16. DOI: 10.1123/jsr.2017-0185
65. Lawrason SVC, Todd KR, Shaw RB, Martin Ginis KA. Physical activity among individuals with spinal cord injury who ambulate: a systematic scoping review. *Spinal Cord.* 2020 Jul;58(7):735-45. DOI: 10.1038/s41393-020-0460-4
66. Quel de Oliveira C, Refshauge K, Middleton J, de Jong L, Davis GM. Effects of Activity-Based Therapy Interventions on Mobility, Independence, and Quality of Life for People with Spinal Cord Injuries: A Systematic Review and Meta-Analysis. *J Neurotrauma.* 2017 May 1;34(9):1726-43. DOI: 10.1089/neu.2016.4558
67. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, McGuinness LA, Stewart LA, Thomas J, Tricco AC, Welch VA, Whiting P, Moher D. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ.* 2021 Mar 29;372:n71. DOI: 10.1136/bmj.n71

Corresponding author:

Dr. Anke Scheel-Sailer
 Swiss Paraplegic Research, Guido A. Zäch Str. 4,
 6207 Nottwil, Switzerland
anke.scheel-sailer@paraplegie.ch

Please cite as

Irrgang S, Himmelhaus S, Allek K, Bartholet C, Bersch-Porada I, Curt A, Huber B, Kuhn D, Kynast K, Weidner N, Scheel-Sailer A. Rehabilitation of the lower extremities, standing and walking function in people with spinal cord injury or disease: Guideline of the German-Speaking Medical Society for Spinal Cord Injury. *GMS Ger Med Sci.* 2025;23:Doc02. DOI: 10.3205/000338, URN: urn:nbn:de:0183-0003383

This article is freely available from

<https://doi.org/10.3205/000338>

Received: 2024-09-05

Published: 2025-06-02

Copyright

©2025 Irrgang et al. This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 License. See license information at <http://creativecommons.org/licenses/by/4.0/>.