BALNEO RESEARCH Balneo and PRM Research Journal
English Edition
e ISSN 2734 - 8458 p ISSN 2734 - 844X ROMANIAN ASSOCIATION OF BALNEOLOGY

Review

Systematic literature review related to the theoretical knowledge base for non-invasive monitoring of the biomechanical and viscoelastic properties of the myotendinous complex in patients with complete tetraplegia following cervical spinal cord injury

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Citation: Cristea A.A., Anghelescu A., Onose G. - Systematic literature review related to the theoretical knowledge base for non-invasive monitoring of the biomechanical and viscoe-lastic properties of the myotendinous complex in patients with com-plete tetraplegia following cervical spinal cord injury
Balneo and PRM Research Journal **2025**, *16(1): 798*

Academic Editor(s):
Constantin Munteanu

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Received: 16.02.2025
Published: 31.03.2025

Reviewers:
Mihai Hoteteu
Manoj Kumar

Publisher's Note: Balneo and PRM Research Journal stays neutral with regard to jurisdictional claims in published maps and institutional af-filiations.

Abstract: Spinal cord injuries (SCI) are severe injuries of the spine and spinal cord with major consequences on the functionality and quality of life of patients [1,2]. These may include neurological injuries, such as tetraplegia, as well as non-neurological injuries affecting the vertebral structures and adjacent tissues [1,2]. Spinal cord injuries have immense disabling potential, and therapeutic options are limited [3]. Currently, there are no neuroprotective agents [5] to counteract damage or stimulate repair processes following spinal cord trauma. Thus, there is no cure for spinal cord injuries [4].The goal of our doctoral study in which we explore this pathology is to monitor the evolution of the bio-functional parameters of the muscles and tendons of the upper and lower limbs using the MYOTON device, to improve—if necessary—the neuro-recovery programs for tetraplegic patients, lead-ing to more promising results and an improvement in the patient's quality of life. We conducted a comprehensive literature search across multiple databases, following the internationally recognized and evidence-based PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) system. Using the PRISMA reporting system, we entered keywords, as well as keyword syntaxes, into multiple international databases, such as Elsevier, PMC, PubMed, and PEDro, to find relevant articles published between 01.01.2021 and 31.12.2023. As a result of using the PRISMA system, we obtained 91 articles published in English in ISI-indexed journals (Institute for Scientific Information); however, after eliminating duplicates and conducting a screening based on inclusion and exclusion criteria, only 3 articles were found to be relevant to our doctoral study. Nevertheless, the relevance of these articles to our doctoral study is insignificant due to the uniqueness of the topic we are addressing. Moreover, there were multiple knowledge gaps found in the aforementioned studies, such as single-case study limitation, lack of follow-ups, exclusion of spinal cord injury patients, lack of comparison with other rehabilitation methods and lack of clinical guidelines. We hope that through this doctoral study, we will achieve our primary goal, namely, utilizing the MYOTON device to monitor the biofunctional parameters of muscles and tendons, as well as gaining a deeper understanding of the evolving pathophysiology of the myotendinous complex in individuals with complete tetraplegia following spinal cord injury. Achieving our goals will help contribute with new knowledge in the neurorehabilitation field, as well as improve the patient's quality of life and facilitate their socio-professional reintegration.

Keywords: Tetraplegia, Spinal cord injury, Myoton, Neurorehabilitation

1. Introduction

Spinal cord injury (SCI) is a severe, life-altering neurotrauma with a significant disease burden. It results in immediate and permanent neurological deficits below the level of injury due to the disruption of neural pathways. SCI is frequently linked to higher morbidity and early mortality, placing considerable strain on the emotional, physical, and social well-being of affected individuals [6].

It is estimated that between 250,000 and 500,000 people worldwide experience a spinal cord injury (SCI) each year [7,8]. The incidence of spinal cord injuries in the USA is 54 cases per 1 million people (17,700 new cases annually) [9], with over 60% being traumatic [10]. Men account for 78% of the cases, and the average age (due to demographic aging) has shifted from 30 years in the 1970s to over 40 years today [11,12,13]. In Europe, approximately 40% to 50% of spinal cord injuries (SCI) are the result of road accidents, and most occur in young people [14].

In Romania, the incidence of SCI was 419 new cases (0.019‰) in 2008 and 407 in 2009 (0.0185‰) – possibly as a consequence of the economic crisis [15]. The incidence of spinal cord injuries (SCI) varies across regions in Romania. A study conducted in Constanța County between 2017 and 2021 reported an annual incidence rate of 2.48 per 100,000 inhabitants, with a male-to-female ratio of 5:1 and a mean age at injury of 47.5 years [16]. Another study from Oradea Emergency County Clinical Hospital during 2017-2021 included 40 patients, with a higher frequency of central spinal cord injury syndrome at the cervical level (35%), followed by anterior spinal cord injury syndrome (22.5%) [17]. These findings underscore the importance of regional studies to understand the incidence and prevalence of SCI in Romania, as well as the need for targeted prevention and management strategies.

Spinal cord injuries are classified into neurological and non-neurological [18]. Neurological injuries involve damage to the spinal cord and are classified based on the level and severity of the injury[19]. Thus, they are classified in complete injuries, characterized by a total loss of motor and sensory functions below the level of injury, and incomplete injuries, where motor and/or sensory functions are partially preserved below the level of injury [18]. Non-neurological spinal injuries refer to structural damages that do not directly affect the spinal cord but can compromise the stability of the spine. These include vertebral fractures, vertebral dislocations, and injuries to the ligaments and intervertebral discs [18].

The prognosis for patients with spinal cord injuries varies depending on the severity and location of the injury. Thus, only 10% of complete tetraplegics and 4% of complete paraplegics will become incomplete after 1 month from the onset of the spinal injury (including SCI) [19].

Complete injuries have a more reserved prognosis compared to incomplete ones. However, early interventions and intensive rehabilitation programs can significantly improve long-term outcomes [1,2].

Tetraplegia is a severe form of paralysis that involves all four limbs and the trunk, leading to partial or total loss of motor and sensory function. It results from injury to the cervical myelomeres (C1-T1), leading to varying degrees of paralysis and loss of sensory and motor functions below the level of the injury [1,2]. From an etiological perspective, the most common causes of tetraplegia are traumatic injuries to the cervical vertebrae (C1-C7). Other causes include degenerative diseases (multiple sclerosis, ALS, syringomyelia), tumors, infections, or vascular pathologies [20].

The vast majority of high spinal cord injuries (C1-C4) are incompatible with life. Therefore, complete tetraplegia is considerably more severe than complete paraplegia and is one of the most severe and debilitating conditions in human pathology. Tetraplegia can also affect the functions of internal organs and lead to respiratory difficulties and other systemic problems. The severity of the disability depends on the location and extent of the spinal cord damage [1,2].

Table 1. Tetraplegia classification

Complete tetraplegia (spinal cord transection) – ASIA Grade A	In complete tetraplegia, there is a total loss of motor and sensory functions below the level of the injury. The patient has no movement or sensation in the upper and lower limbs. Injuries at the C1-C4 level are the most severe and can lead to complete paralysis of the upper and lower limbs, with respiratory impairment due to diaphragm paralysis. [21,22].
Incomplete Tetraplegia – ASIA Grades B, C, D, E	In incomplete tetraplegia, the patient may retain certain motor or sensory functions below the level of the injury. These functions can vary significantly depending on the severity and exact location of the injury.Injuries at the C5-C8 level lead to varying degrees of loss of function in the arms and hands, depending on the specific level of the injury [21,22].

In our doctoral study, we aimed to use multiple clinical-functional assessment tools, such as: the American Spinal Injury Association (AIS) Impairment Scale, Spinal Cord Independence Measure (SCIM), Functional Assessment Measure (FIM+FAM), and Functional Ambulation Classification (FAC). Among these, the most important in our study is the ASIA scale (American Spinal Injury Association Impairment Scale). This is a standardized instrument used to assess and classify spinal cord injuries, providing a comprehensive framework for evaluating sensory and motor function in patients with spinal cord injuries, helping to guide treatment strategies and predict prognosis. The ASIA Exam Chart classifies the severity of the injury into five main categories (A-E) that describe the severity of motor and sensory impairment [22,23].

Table 2. ASIA Exam Chart [22,23]

Grade A	Complete injury – No motor or sensory function is preserved below the level of the injury [22,23].
Grade B	Sensory incomplete injury – Sensory function is preserved below the level of the injury and includes the sacral segments S4-S5, but motor function is lost [22,23].
Grade C	Motor incomplete injury – Incomplete injury with motor function preserved below the neurological level, and more than half of the key muscles below the neurological level have a muscle grade of less than 3 (on a scale from 0 to 5) [22,23].
Grade D	Motor incomplete injury – Incomplete injury with motor function preserved below the neurological level, and at least half of the key muscles below the neurological level have a muscle grade of 3 or greater [22,23].
Grade E	Motor and sensory function is normal [22,23].

The neurorehabilitation personalised program usually begins shortly after the accident, often in a hospital or a ward specialised in spinal cord injury care. A thorough evaluation follows, involving a multidisciplinary team of professionals.

This evaluation forms the basis for setting recovery goals that are specific, measurable, attainable, relevant, and time-based (SMART goals – specific, measurable, attainable, relevant, time-based) [24]. Understanding the specific level of the cervical injury is crucial for developing a comprehensive rehabilitation plan. The neurorehabilitation program proceeds as follows [1, 2, 25]:

1. **Rehabilitative care:** These are the most important, as during the first 4 weeks post-surgery, mobilization is contraindicated, and the patient is bedridden. Therefore, during the post-acute phase, prevention of complications is carried out. These complications include immobilization syndrome and maintaining autonomy by learning 'tricked' movements performed with other body segments and/or the other limb, or by using assistive devices. Other rehabilitative care measures include: changing position in bed to prevent pressure sores, bladder catheterization, nasogastric feeding, and bronchial drainage.
2. **Physical therapy and physiotherapy:** Adapted to strengthen unaffected muscles and improve functional mobility.
3. **Occupational therapy:** Focuses on improving the ability to perform daily activities using adaptive techniques and equipment.
4. **Assistive technology:** Includes customized wheelchairs, communication devices, and home modifications to support independence.
5. **Psychological support:** Essential to address the emotional and psychological impact of tetraplegia.
6. **Vocational and community reintegration.**
7. **Long-term management and follow-up.**

Unfortunately, when it comes to tetraplegic patients the available rehabilitation methods are insufficient. These patients face several challenges on their rehabilitation journey that limit its effectiveness. Key issues include the following:

1. The rehabilitation program is long, demanding and costly. The injuries of SCI patients lead to serious disabilities which result in psychosocial and economic problems. [26]
2. Short hospitalization periods for rehabilitation programs result in patients being discharged without acquiring the necessary functional skills. [27]
3. When it comes to tetraplegic patients there is a mandatory need for complex rehabilitation approaches. Tetraplegic patients often require powered wheelchairs controlled by chin movements, sip and puff, or head arrays, especially for individuals with C1-4 injuries. Those with C5 injuries may use hand-controlled powered wheelchairs, while C6-8 injuries might allow for manual wheelchair use. [28]
4. Limited functional improvement depending on the severity of the injury. For instance, a study on C6 tetraplegic patients documented improvements during rehabilitation using the modified Barthel Index, but the overall functional gains were modest. [29]

In the neurorehabilitation process, an important part is also represented by biomechanical assessment, which involves analyzing forces and movements to understand the mechanical function of the body. This is done through the evaluation of muscle function, gait analysis (in the case of incomplete tetraplegia), and the use of advanced technological tools for precise biomechanical assessments, allowing for personalized rehabilitation programs. Through biomechanical evaluation, we obtain important information about the myotendinous complex, such as [30,31,32]:

1. **Viscoelasticity:** A fundamental property of muscles, allowing them to respond both elastically and viscously to mechanical stress.
2. **Myoplasticity:** Refers to adaptive changes in muscle tissue in response to injury or altered levels of activity. In the case of spinal cord injuries and tetraplegia, myoplastic changes can significantly affect muscle function and overall mobility.
3. **Myotonometry:** A non-invasive method used to measure muscle tone, rigidity, and elasticity. In the context of spinal cord injuries and tetraplegia, myotonometry provides valuable data for assessing muscle properties and monitoring progress in recovery.

In our doctoral study, we aimed to assess the properties of the myotendinous complex using the Myoton device. Myoton is a non-invasive evaluation device used to measure the mechanical properties of muscles and soft tissues, providing valuable data on muscle tone, rigidity, and elasticity, making it an essential tool in medical, sports, and rehabilitation research [32,33, 34].

The Myoton device works by applying a small mechanical force to the surface of the skin above the muscle. The device uses a short mechanical impulse, after which it measures the muscle's response to this stimulation. The response is analyzed to determine the mechanical properties of the muscle, such as [35]:

1. **Muscle tone**: The passive tension state of the muscle at rest.
2. **Muscle stiffness**: The resistance of the muscle to deformation.
3. **Muscle elasticity**: The muscle's ability to return to its original shape after deformation.
4. **Creepability**: The Deborah number (De) is a dimensionless value commonly utilized in rheology to describe the flow behavior of materials under particular conditions. It captures the concept that, over time, a material resembling a solid may flow, or a material resembling a fluid may behave like a solid when subjected to rapid deformation [36].

The Myoton device is used to assess patient progress during rehabilitation programs, allowing therapists to adjust treatments based on the measured muscle responses. Studies have shown that precise measurements of muscle tone and stiffness can guide personalized treatments for conditions such as cerebral palsy, muscle injuries, and neurological disorders. The device can assist in diagnosing muscular and neuromuscular conditions by identifying abnormalities in the mechanical properties of muscles. For example, increased stiffness may indicate the presence of muscular dystrophy or myopathy [35].

2. Methods

To identify the current state of knowledge related to this doctoral thesis, we used the PRISMA reporting system (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). The PRISMA reporting system is a concise set of evidence-based guidelines aimed at assisting scientific authors in reporting a broad range of systematic reviews and meta-analyses, mainly used to assess the benefits and risks of health interventions. It emphasizes how authors can ensure transparency and completeness in their reporting [38].

Using the PRISMA reporting system, we entered keywords, as well as keyword syntaxes, into multiple international databases, such as Elsevier, PMC, PubMed, and PEDro, resulting in a considerable number of articles published in English between January 1st, 2021, and December 31st, 2023.

We have also conducted a screening based on the inclusion and exclusion criteria of our doctoral study. Thus, we included studies where patients met the age criteria (at least 18 years old) and were diagnosed with post-traumatic tetraplegia in the sub-acute phase (less than 3 months after the traumatic injury) and sub-chronic post-operative phase (less than 6 months after the traumatic injury) and we excluded studies with pediatric patients (under 18 years old).

Our reasoning for selecting the aforementioned databases for PRISMA (Elsevier, PMC, PubMed, PEDro) is based on their wide coverage of disciplines (from general medicine to specialized fields like physiotheraphy), their rigorously selected and peer-reviewed articles which ensure inclusion of high-quality evidence in our systematic review, their accessibility to a mix of original research, clinical trials and other relevant literature necessary for a comprehensive PRISMA search and, last but not least, for their reliability- these databases being trusted by researchers and clinicians worldwide, ensuring that the evidence found is credible and reliable for evidence synthesis.

Table. 3 Keywords and key-syntaxes used in PRISMA reporting system

Keywords and key-syntaxes	**Elsevier**	**PubMed**	**PMC**	**PEDro**	**Total**
"traumatic spinal cord injury" + "tetraplegia" + "viscoelastic"	0	0	6	0	6
"traumatic spinal cord injury" + "tetraplegia" + "visco-elastic "	0	0	0	0	0
"traumatic spinal cord injury" + "tetraplegia" + "biomechanical assessment"	0	0	0	0	0
"traumatic spinal cord injury" + "tetraplegia" + "myoplasticity"	0	0	0	0	0
"traumatic spinal cord injury" + "tetraplegia" + "myotonometry"	0	0	0	0	0
"traumatic spinal cord injury" + "tetraplegia" + "skeletal muscle"	0	0	70	0	70
"traumatic spinal cord injury" + "quadriplegia" + "viscoelastic"	0	0	7	0	7
"traumatic spinal cord injury" + "quadriplegia" + "visco-elastic "	0	0	0	0	0
"traumatic spinal cord injury" + "quadriplegia" + "biomechanical assessment"	0	0	0	0	0
"traumatic spinal cord injury" + "quadriplegia" + "myoplasticity"	0	0	0	0	0
"traumatic spinal cord injury" + "quadriplegia" + "myotonometry"	0	0	0	0	0
"traumatic spinal cord injury" + "quadriplegia" + "skeletal muscle"	0	0	36	0	36
Total	0	0	119	0	**119**

All 91 articles were published in ISI (Institute for Scientific Information) indexed journals. Of these 91 articles, only 3 were relevant. Nevertheless, the relevance of these articles to our doctoral study is insignificant due to the uniqueness of the topic we are addressing.

The decision to choose this research topic for this doctoral thesis stems from its insufficient representation in the specialized literature. As observed in the previous slides, the PRISMA reporting system initially identified 91 eligible articles, but after thorough research, it became apparent that only 3 articles mentioned the Myoton device. However, none of these articles used it on tetraplegic patients, proving the uniqueness of our doctoral study.

Thus, we can conclude that this research topic is highly relevant, as it has not been sufficiently explored in the specialized literature, which presents a significant advantage for us in terms of the opportunity to make personal contributions to the fields of neurorehabilitation and tetraplegic patient management.

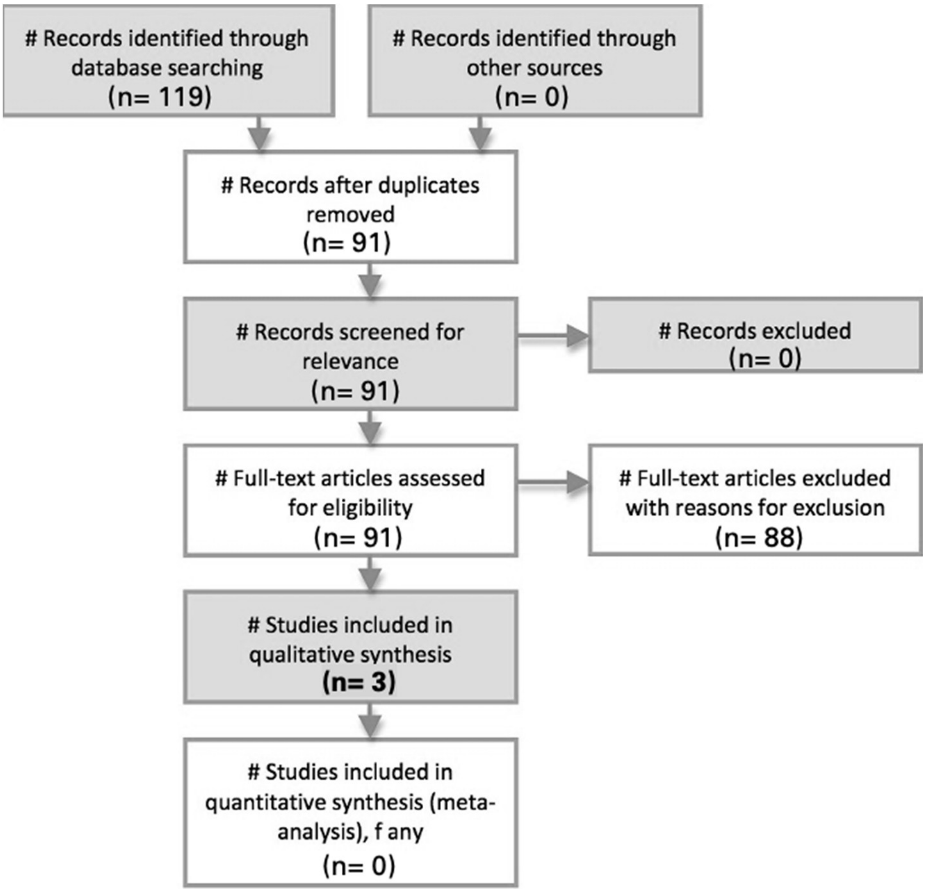

Figure 1. PRISMA diagram relating to our systematic review of literature

The use of this device may lead to a better understanding of the biomechanical evolution of muscles in tetraplegic patients, helping us develop specific neurorehabilitation programs tailored to the individual needs of each patient. Moreover, by implementing specifically designed neurorehabilitation programs, we aim to improve the quality of life for each patient and, additionally, facilitate their socio-professional reintegration.

We intend to conduct a prospective longitudinal observational study, following 30 post-operative tetraplegic patients from the moment of transfer during the early subacute phase (under 3 months) and sub-chronic phase (under 6 months). According to the study protocol, we will assess the myo-elastic properties of key muscles in the upper and lower limbs of patients with cervical spinal cord injuries, classified as ASIA Grade A.

For the upper limbs, we will measure the properties of the deltoid, biceps brachii, brachioradialis, ulnar carpal flexor muscles, while for the lower limbs, we will assess the properties of the rectus femoris, anterior tibialis, lateral gastrocnemius, and medial gastrocnemius muscles. Additionally, we will measure the properties of the superficial patellar and Achilles tendons.

The evaluation of the myotendinous complex will first take place at rest, followed by post-passive mobilization of both the lower limbs using the MOTOmed letto device and the upper limbs using the passive robotic physiotherapy gloves (Sentinex). Mobilization will last 30 minutes, and measurements will be taken twice a week to ensure precise results during the hospitalization period, with the patient's informed consent. The doctoral study will be conducted in the Neuromuscular Rehabilitation Department of the "Bagdasar-Arseni" Emergency Clinical Hospital in Bucharest and will be approved by the hospital's Ethics Committee.

In the clinical-functional evaluation of patients included in the study, in addition to the Myoton device, the following assessment charts will be used: American Spinal Injury Association (AIS) Impairment Scale, Spinal Cord Independence Measure (SCIM), Functional Assessment Measure (FIM+FAM), Functional Ambulation Classification (FAC), Muscle Power Scale (MRC), Range of Motion Scale (ROM), Activity of Daily Living Scale (ADL), and Quality of Life Scale (QOL).

Statistical analysis will be performed using SPSS v. 24 (Statistical Package for Social Sciences, version 24) and Microsoft Excel 2007. It will include demographic data, descriptive statistics, comparison tests, parametric or non-parametric differentiation tests depending on data normality, and potentially correlation tests, graphical representations through charts and/or histograms. The results will be considered statistically significant if $p < 0.05$. A 95% confidence level will be used, with corresponding confidence intervals for specific calculations.

3. Results and discussion

By using the Myoton device on tetraplegic patients, we hope to gain a better understanding of the evolving pathophysiology of the myotendinous complex in key muscle groups of the upper and lower limbs, through the quantitative assessment of the biomechanical properties of tendons and muscles during the progression from the early post-acute stage to the subchronic stage. Additionally, we hope to contribute to the improvement of existing rehabilitation programs by gaining a deeper understanding of the biomechanical properties of the musculature.

Myotonometry, measured by devices like MyotonPRO, offers a novel approach to muscle assessment, providing objective measurements of muscle mechanical properties. The following list provides a comparison between Myoton technology and traditional muscle assessment tools.

I. Measurement Parameters

Myoton Technology: Quantifies muscle properties such as tone, stiffness, and elasticity through non-invasive mechanical impulses.[40]

Traditional Tools: Rely on subjective clinical scales like the Modified Ashworth Scale (MAS) and Tardieu Scale (TS), which assess muscle tone and spasticity based on manual manipulation and clinician observation.[41,42]

II. Objectivity and Reliability

Myoton Technology: Provides objective, quantifiable data with high reliability. Studies have demonstrated its validity and reliability in assessing muscle viscoelastic properties, particularly in populations like stroke survivors.[40,43]

Traditional Tools: Subject to inter-rater variability due to their reliance on clinician judgment, leading to potential inconsistencies in assessments.[44]

III. Ease of Use and Accessibility

Myoton Technology: Handheld, portable devices that are easy to operate, allowing for quick assessments without extensive training.[44]

Traditional Tools: Require experienced clinicians to perform assessments accurately, and the subjective nature may necessitate repeated evaluations for consistency.

IV. Applicability Across Populations

Myoton Technology: Effective in diverse populations, including athletes, elderly individuals, and patients with neuromuscular disorders, providing consistent measurements across different muscle groups. [37]

Traditional Tools: Primarily used in clinical settings for patients with neurological impairments; their applicability in other populations is limited.

V. Integration with Modern Technologies

Myoton Technology: Can complement other diagnostic tools, such as electromyography (EMG) and imaging techniques, offering a comprehensive assessment of muscle function. [37]

Traditional Tools: Standalone assessments that may not integrate seamlessly with advanced diagnostic technologies.

In order to demonstrate the uniqueness and importance of our doctoral study, we have conducted the priorly mentioned PRISMA reporting system search, from which we concluded that the three resulted articles were not of high enough relevance for our undergoing research. Thus, we have summarized and compared the findings from these three articles in the following tables.

Table. 4 Comparison between the three articles resulted in the PRISMA search

Study	Main Focus	Methods Used	Key Findings	Use of Myoton Device?
Go-Kart & SCI Rehabilitation *(Farì et al., 2023)* [45]	Effects of go-kart driving on muscle spasticity in SCI	- Modified Ashworth Scale - **MyotonPro** (for tone & stiffness)	- **Significant reduction in spasticity** immediately after driving. - Effects lasted **~20 days** but returned to baseline at 4 weeks. - Possible **WBV (Whole-Body Vibration) effect**.	**YES.** Used **MyotonPro** to measure **muscle tone & stiffness** in leg muscles before and after driving.
Exoskeleton Training & Muscle Activity *(Kim et al., 2021)* [46]	Adaptation of muscle activity over 15+ sessions of exoskeleton training	- Electromyography (EMG) - **MyotonPro** (for muscle tone, stiffness, elasticity)	- At least **15 training sessions** needed to **reduce muscle strain**. - **Upper body compensation** reduced over time. - Muscle **tone & stiffness decreased** gradually.	**YES.** Used **MyotonPro** to measure **muscle characteristics** during static postures.
Spasticity Assessment Review *(He et al., 2023)* [47]	Evaluating traditional & modern methods of spasticity assessment	- Review of MAS, TS, Biomechanics, Imaging (MRI, NIRS) - AI & Robotics-based assessments	- **Traditional scales (MAS, TS) lack standardization**. - **Portable sensors & AI models** improve accuracy. - **Myotonometry is a promising tool** but needs more validation.	**NO.** Mentioned **Myotonometry** as a **new technology**, but did not conduct original measurements.

Table. 5 Summary of the three articles resulted in the PRISMA search

Aspect	Article 1: Quantitative Assessment of Spasticity: A Narrative Review [47]	Article 2: Is There a New Road to Spinal Cord Injury Rehabilitation? [45]	Article 3: Preliminary Assessment of Muscle Activity and Muscle Characteristics during Training with Powered Robotic Exoskeleton [46]
Purpose	Review of novel methods and technologies for assessing spasticity.	Case report on the effects of go-kart driving on muscle spasticity for spinal cord injury patients.	Study on muscle activity during robotic exoskeleton training in healthy adults.
Study Type	Narrative review.	Case report.	Repeated-measures study.
Key Focus	Spasticity assessment techniques and new technological approaches.	Investigation of a novel rehabilitation activity (go-kart driving) for spasticity reduction.	Muscle activity and characteristics during robotic exoskeleton training.
Population	No specific population, literature review.	Spinal cord injury patient.	Healthy adults (16 participants).
Methods	Review of existing research and technologies.	Case report, anecdotal evidence, and observational methods.	Repeated-measures, 7-week study with 3 sessions per week.
Key Findings	New methods and technologies can improve spasticity assessment.	Driving a go-kart was found to impact muscle spasticity.	Robotic exoskeleton training decreases muscle activity after 15 sessions with minimal load on muscles.
Technological Focus	Various technological approaches for spasticity assessment.	Go-kart driving as a new rehabilitation technique.	Powered robotic exoskeleton.
Clinical Relevance	Useful for understanding advancements in spasticity monitoring.	Explores an unconventional approach for spasticity management in spinal cord injury.	Provides insights into optimal robotic exoskeleton training durations and muscle impact.
Conclusion	Highlights new potential approaches for assessing spasticity.	Go-kart driving might be a promising adjunct to rehabilitation for spasticity.	At least 15 training sessions are needed to minimize musculoskeletal strain with exoskeleton use.

4. Conclusions

Considering the lack of scientific articles on this topic, we can conclude that this doctoral study takes a unique approach in the field of neuromuscular rehabilitation. If, as a result of this doctoral research, the beneficial contribution of using MyotonPro as an objective method for monitoring the biomechanical properties of the myotendinous complex during physical-kinetic therapy in post-spinal cord injury tetraplegic patients is identified, it could lead to more effective treatment plans aimed at optimizing the neuro-rehabilitation process.

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