



# Muscle Tonus Evaluation in Patients with Neurological Disorders: A Scoping Review

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## Abstract

**Purpose** The aim of this work is to provide an overview of studies that explore methods of assessment for muscle tone in patients with neurological disorders.

**Methods** A scoping review was conducted on the PubMed, IEEE/IET Electronic Library, Web of Science, Scopus, Cochrane, Bireme, Google Scholar, and Science Direct databases. The characteristics analyzed were types of tonus; neurological disorder diagnosis; the method used for assessing muscle tone and the muscle under evaluation. The search found a total of 1593 studies, and after the filtering process, 84 were selected.

**Results** The most reported method for assessing muscle tonus was the Modified Ashworth Scale, applied to post-stroke patients. Only two studies evaluated patients with hypotonia. Some studies presented quantitative devices for the evaluation as an alternative to the most commonly used methods. The most evaluated muscles were the elbow and the knee flexors.

**Conclusion** The results show the importance of properly assessing the different types of muscle tone, and show a lack in evaluating hypotonia. The results also demonstrate the need to create new devices that provide more objective and reliable methods that can evaluate more than one type of tonus.

**Keywords** Muscle tonus · Neurological disorder · Evaluation · Scoping review

## 1 Background

The muscles of the human body have a state of permanent tension: even when the muscle is in a resting state, there is a base degree of contraction known as muscle tone or tonus. The presence of adequate muscle tone is essential, as this allows one to perform functions such as activities of daily living (ADL) [1]. Individuals with neurological injuries that may compromise the central nervous system (CNS) or the peripheral nervous system (PNS) may lose the natural ability to control the level of the tonus and display very low or

very high resting tone, known as hypotonia and hypertonia, respectively [2].

Hypotonia, hypertonia and rigidity are the most common disorders found in the muscle tone. Hypotonia can be characterized by lower tonus, where the muscle is not able to support the joint well; therefore, it has little to no resistance to external movements, making it easier for another person to manipulate the joint. This type of disorder can be caused by conditions such as cerebral palsy (CP) [3] and peripheral neuropathies. Hypertonia is defined by an abnormally high tonus, and it is otherwise known as spasticity. This type of disorder causes an increase in resistance to movement and results in limitations to the joint [4]. High values of tonus may also prevent movement, coordination and learning. Hypertonia may be present in numerous clinical conditions, such as traumatic brain injury (TBI), stroke or certain neurodegenerative processes [5]. Rigidity can be defined by the presence of very high muscle tone, which severely restricts any kind of movement, and is often present in disorders such as Parkinson's disease (PD) [6].

Muscle tone assessments using validated methods are essential for clinical decisions. The results of such

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assessments can be used to find the best course of treatment for each individual patient, identify concerns about the degree of impairment of the evaluated limb, and provide assistance in monitoring the progress of patients undergoing a particular treatment. [7].

Currently, there are several reports in the literature from studies that performed evaluation of muscle tone in patients with neurological disorders using both subjective and objective methods. Subjective methods may include ordinal measurements, such as the Modified Ashworth Scale (MAS), which is an instrument capable of assessing limb resistance to movement [8, 9]. Among the objective methods, some of the quantitative variables measured are kinematic components [10], torque [11, 12], and electromyography [6, 13].

The purpose of this scoping review is to provide an overview of studies involving methods of assessment of muscle tone in patients with neurological disorders, using both objective or subjective methods. Our main goal is to highlight potential trends, as there is currently no gold standard in tonus evaluation either in clinical practice or in the literature.

## 2 Methods

### 2.1 Protocol and Registration

This review was registered in OSF (<https://doi.org/10.17605/OSF.IO/BCRHT>). A scoping review was performed on studies that evaluated the muscle tone, following the methodological recommendations of the Joanna Briggs Institute for systematic scoping reviews [14]. The target population was composed of individuals with neurological disorders, and eligibility factors were defined and adopted to find potential studies in literature. Studies were considered eligible if they met the following inclusion criteria:

- (1) Participants of the study presented neurological and/or muscular disorders (with no limitations based on age or sex).
- (2) The study was composed of randomized clinical trials, randomized controlled trials, clinical trials, case reports, or cohort study.
- (3) The study evaluated tonus using either subjective or objective methods.
- (4) Full text written in English.

Exclusion criteria were:

- (1) The research was conducted with healthy participants in an experimental group.
- (2) Text written in another language (other than English).
- (3) The study was a meta-analysis or systematic review.

- (4) Ongoing research (poster, patent, chapter of book).

### 2.2 Search Strategy

The search was conducted without any time restriction, ranging from the creation of each database to March 2021. We systematically searched electronic databases or potentially relevant papers, including PubMed, IEEE/IET Electronic Library, Web of Science, Scopus, Cochrane, Bireme, Google Scholar, and Science Direct.

The following search query was used in all databases: [(muscle OR muscular) AND (tonus OR tension OR Tightness OR Stiffness)] AND (evaluation OR assessment OR estimation) AND [(neurological AND (disorder OR disturb)) OR (central AND nervous AND system AND injury) OR (peripheral AND nervous AND system AND injury)].

### 2.3 Study Selection

After executing the search strategy in each of the databases, the list of eligible works was extracted and organized in Rayyan – Intelligent Systematic Review [15]. At first, studies were filtered based on the reading of title and abstract. The studies that passed the first filtering process were read in full; those that met the criteria were included for analysis in this review.

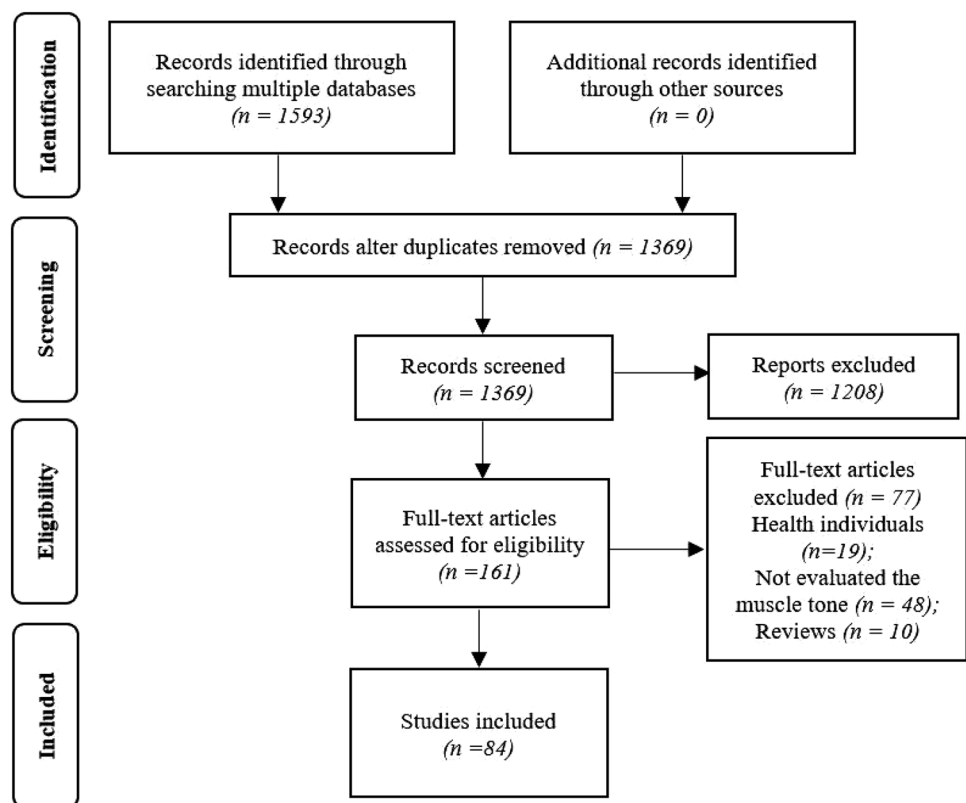
Subsequent data extraction and quality assessment of the selected studies were performed, in which title, abstract, and full text of each paper were reviewed by 2 reviewers (AR and CA). Disagreements between reviewers were resolved by consensus. If no consensus could be reached, a third reviewer (EN) would decide. All the reviews checked if the studies included were consistent and followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram [16].

### 2.4 Data Analyses

Several characteristics were extracted from each of the selected studies, to be subsequently organized and formatted into a table for better visualization of the results. The characteristics extracted were the following: type of study, year of publication, sample size, type of neurological disorder, type of assessment used, method to assess muscle tone and assessed limb.

## 3 Results

The flow diagram of the filtering process applied to all databases is presented in Fig. 1. After eliminating duplicate works, we found 1369 studies from 8 different databases. Those 1369 underwent a screening process by title and

**Fig. 1** Flow diagram illustrating the phases of the scoping review

abstract, and 1208 studies were excluded for not meeting the eligibility criteria. In the third step, the 161 remaining studies were fully read, resulting in a total of 84 studies included in this scope review. The other 77 papers were excluded for different reasons: 19 were studies that evaluated muscle tone of healthy individuals rather than individuals with disability; 48 studies did not assess tonus; and 10 papers were reviews, and therefore should not be included.

As stated previously, the characteristics of each study (such as type of tonus and assessment tool) are summarized on Table 1. All three types of muscle tone (hypotonia, spasticity, and rigidity) were discussed among the studies selected. Clinical trials were executed to evaluate the proposed methods in the aforementioned studies with individuals with impairment in the muscle tone, with several methods of tonus evaluation explored in those studies. The Modified Ashworth Scale (MAS), an ordinal measure created to evaluate the resistance to passive movement, was the most commonly applied method among the selected studies, being used in 42 out of 84 works. Another method of assessment often used incorporated quantitative devices (7 out of 84 studies) to evaluate the muscle tonus. Lastly, electromyography is an alternative method (used in a total of 7 studies), where the tonus is measured by muscle activity.

The least type of tonus impairment found in the literature was hypotonia, discussed in only 2 of the 84 studies [17, 18]. Both studies assessed upper limb condition

of individuals. In [17], the tonus was measured using an electro-mechanical machine, and [18] used the method of resistance to passive movement to assess participants. On the other hand, spasticity was the most common tonus impairment assessed, mainly due to the existence of the MAS, which is specifically designed for assessment of this impairment, and is widely known and applied in clinical settings.

Table 2 displays the main muscles and the type of tonus impairment focused in the assessment. Regarding the muscles evaluated, the most presented were flexors and extensors of the knee joint (29 studies) and elbow (26 studies), as they are most often affected by disorders while also having the greatest impact on the quality of life.

Regarding the distribution of studies across databases, Fig. 2 shows that the majority of studies (approximately 63.9%) were taken from the PubMed database. The remainder of the studies were selected from the other databases, with Scopus, Web of Science and Bireme being those presenting the most expressive percentages.

Figure 3 presents the number of studies included in this scoping review per decade. Most of the studies recovered were published between 2011 and 2020 (approximately 55.3%). This suggests an increase of over 100% of papers researching the subject in the last decade in comparison with the previous, indicating the growing interest in assessment of muscle tone for individuals with neurological disorders.

**Table 1** Methods of tonus assessment and type of tonus characteristics in the included studies

Studies	Type of tonus	Method of tonus evaluation	Percentage of method use (%)*	
[17]	Hypotonia	Machine measurement	0.84	
[18]		Resistance to passive movement	0.84	
[8, 11, 13, 19–57]	Spasticity	MAS	50	
[42, 58–63]		EMG	8.34	
[64–67]		Ashworth scale	4.76	
[36, 45, 68, 69]		Pendulum test	4.76	
[12, 24, 26, 56, 57, 70]		Tardieu scale	7.14	
[13, 20, 40, 60, 62]		Fulg-Meyer	5.95	
[40, 45, 60, 71, 72]		Stretch Reflex test	5.95	
[10–13, 43, 45, 73]		Quantitative device	8.34	
[26, 48, 54, 57]		Ultrasound imaging	4.76	
[41, 63, 74]		Myometer or Dynamometer	3.57	
[75–78]		Rigidity	Ultrasound elastography	4.76
[17, 79–84]			Quantitative device	8.34
[6, 77, 83, 85, 86]			UPDRS	5.95
[85, 87, 88]			EMG	3.57
[6, 85, 86, 89, 90]	Myometer or Dynamometer		5.95	
[36, 91]	Pendulum test		2.38	
[92]	Overall Stiffness Intensity		0.84	
[93]	Scale of 1+ (mild) to 4+ (very severe)		0.84	
[9, 18]	Stretch Reflex test	2.38		
[9, 36]	MAS	2.38		

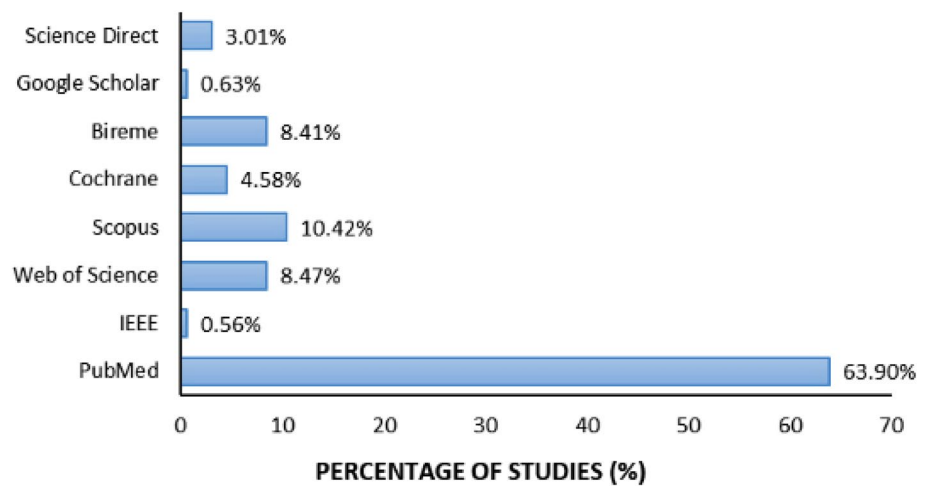
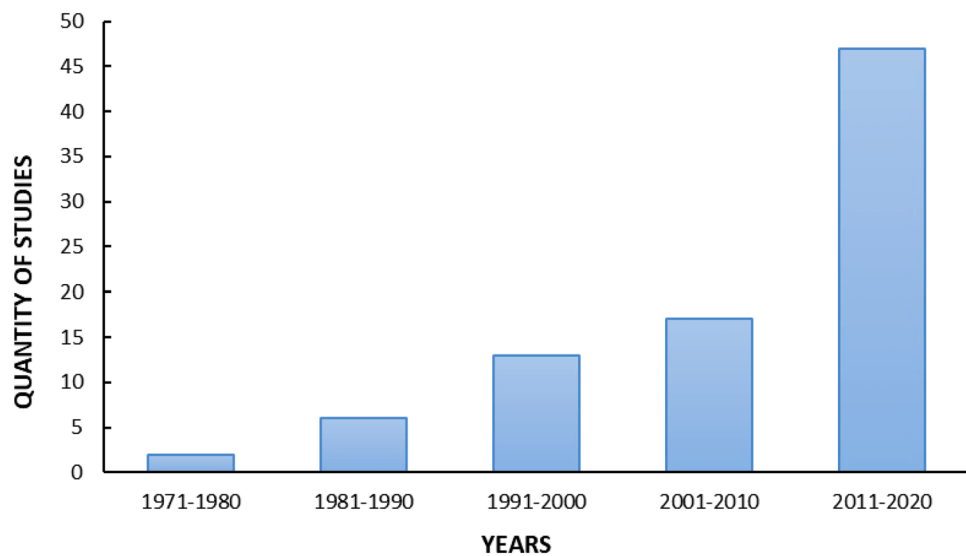
\* Percentage calculated based on the total number of studies selected (84), considering that some studies used more than one method

**Table 2** Type of tonus and the muscles evaluated in the included studies

Studies	Type of tonus	Muscles evaluated	
[17, 18]	Hypotonia	Upper and lower limbs	
[8, 10, 21–25, 31, 32, 38, 39, 43–45, 48, 49, 51–53, 55, 56, 60, 64–70]	Spasticity	Knee flexors and extensors	
[12, 19, 28, 35, 37, 47, 51, 54, 59–61, 63, 71, 74]		Ankle flexors and extensors	
[11, 13, 26–30, 33, 34, 36–41, 45, 46, 49–51, 56–58, 62, 67, 72]		Elbow muscles	
[29, 42, 51, 73]		Wrist muscles	
[49]		Trunk and neck	
[46]		Glenohumeral-scapular	
[79, 80, 84, 86]		Rigidity	Wrist muscles
[75–78, 81, 83, 93]			Biceps brachii muscle
[6, 82]			Muscle belly
[87, 88, 92]			Trunk muscles
[90]			Extensor digitorum and the flexor carpiradialis
[78, 87, 91]			Lower limb muscles
[9, 89]			Ankle dorsiflexors
[85, 92]		Brachioradialis and triceps brachii muscles	

The papers were also divided between subjective and objective methods. Subjective methods depend on the experience of the therapist responsible for conducting the evaluation, such as movement resistance scales, including

MAS [8] and Tardieu scale [70]. Objective methods use quantitative metrics for analysis of the data obtained during assessment, resulting in a numerical value that indicates the degree of muscle tone, without requiring the interpretation

**Fig. 2** Distribution of studies by database**Fig. 3** Quantity of studies selected per decade

of subjective factors such as therapist expertise. One example of an objective method is using electromyography sensors [61] to assess muscle tone based on the muscle activity. Categorizing the papers in subjective and objective methods revealed that the percentage of types of methods used were very similar, with 48.2% of studies using subjective methods and 51.8% using objective methods.

## 4 Discussion

This scoping review included 84 studies investigating different methods for tonus evaluation. The studies selected addressed all types of muscle tone conditions (hypotonia, normal, spasticity, and hypertonia), along with several types of tonus assessment methods. A majority of the studies used clinical tools or subjective methods to provide assessment to muscle tone. However, most recent studies have shifted interest to using new tools and quantitative measurements.

Only two of the studies eligible in the review investigated hypotonia [17, 18]. Consequently, the vast majority of studies found evaluated either spasticity or rigidity. As established in the eligibility screening, all papers selected applied their respective tonus assessment methods in individuals with tonus impairment through clinical trials.

Hypotonia is a condition originating from different health problems, many of which are inherited. It can occur sometimes in individuals with cerebral palsy (CP). For the two studies evaluating hypotonia, the causes of the impairment were cerebellar ataxia [17] and Williams syndrome [18]. However, none of the papers evaluated hypotonia due to peripheral neuropathies and polyneuropathies. This demonstrates the inexistence of methods to assess this type of muscle tone condition.

Hypertonia encompasses both spasticity and rigidity, the first being dependent on the stretching speed [72]. The assessment of hypertonia is critical in clinical diagnosis, as this tonus disorder affects millions of people around the

world [94]. The majority of assessment methods for muscle tone are based on scales such as MAS and Tardieu scale. However, some of the papers also discussed devices using quantitative metrics, showing an increasing search for more reliable means of measurement.

Muscle tone may change when individuals are affected by disorders that impact the CNS. Stroke, for example, is one of the leading causes of death [95], second only to cardiac diseases. In the papers selected for this review, 53 evaluated the muscle tone of post-stroke patients. Stroke is the leading cause of acquired physical disability in adults worldwide [96], including changes in muscle tone, which explains the number of researches involving post-stroke individuals.

The most reported method for assessing muscle tonus in post-stroke patients was MAS. This scale was originally developed for the evaluation of spasticity in post-stroke, although it can be used in other disorders. For example, the MAS can be used alongside Tardieu scale [24] to assess muscle tone condition in patients with cerebral palsy. Most of the studies found concerning Parkinson's disease used quantitative devices or the UPDRS (Unified Parkinson's Disease Rating Scale) to assess the muscle tone of the patients. The UPDRS is a scale developed to be used in combination with other assessment tools to identify disabilities and impairment related to PD, including abnormal muscle tone [97].

Some studies also used the subjective scales (such as MAS and the UPDRS) in combination with quantitative metrics of assessment. Robotic devices have been developed [11, 43], and other authors have used electronic devices [80, 83]. The combination of the two methods demonstrates the importance of validating these new devices in clinical practice, as well as the lack of quantitative devices able to perform this specific function.

The goal of the quantitative devices used to assess muscle stiffness in patients with PD is to obtain higher reliability [79, 80, 82–84]. Sensors such as force transducers [84] and gyroscopes [80] can increase the accuracy of those devices. The studies reported positive outcomes using sensor technology, which reinforces the importance of investing in the development of these technologies using objective metrics of the muscle tone; this can only result in more reliable and efficient evaluations [98, 99]. Despite the increased efforts, the vast majority of researchers are exploring solutions to be applied in spasticity and rigidity measurement, and few for hypotonia.

Subjective assessment methods are still used in most studies selected for the scoping review. The main reasons behind the use of such tools can be attributed to their simplicity, making them useful and accessible in a clinical practice. However, it is also a cause for criticism, since the accuracy of such methods depends entirely on precise clinical observations [100]. As a result, a big challenge is developing

devices that are easily accessible in clinical practice, while being able to demonstrate accurate results [94].

The findings of this scoping review support the idea of developing a method to assess more than one type of muscle tone. As seen previously in the study of [101], the muscle tone of an individual can be altered under certain conditions. For example, a patient suffering a stroke may present more than one tonus impairment during the recovery and rehabilitation period, displaying characteristics attributed to hypotonic individuals during the acute phase of stroke and becoming a spastic individual during the chronic phase of the stroke. Using a single method, it would be possible to analyze such changes more reliably, differently from what is currently possible using ordinal measurements.

While the studies applied assessment methods in different parts of the body, they focused on the upper and lower limbs, which are usually the most affected by any change in tonus [94]. For instance, the muscles of the wrist are some of the most affected by the rigidity caused by Parkinson's disease [79]. However, assessment of the condition of those muscles was conducted in very few of the works found in the literature. In fact, research and development of methods that can be simultaneously applied in different muscles is of great importance, since more information regarding a patient's condition can be obtained from analyzing tonus in more than one muscle group.

#### 4.1 Main Limitations and Clinical Implications

Although this scoping review was conducted following a well-defined protocol, ensuring that the research guidelines were carefully followed, there are limitations inherent to the search parameters and eligibility criteria established. The scoping review provides an overview of the existing evidence regardless of quality. This particular review was limited to studies written in English; as such, potential relevant research reported in other languages were not included in its results.

The assessment of muscle tone in clinical practice bears significance in the creation of new therapies and monitoring of patients with any neurological disorder. The studies included in this scoping review revealed the existing gap generated by the lack of methods capable of evaluating hypotonia, as well as the growth of studies focused in spasticity and rigidity evaluation methods in the last decade.

## 5 Conclusion

Findings of this study indicated a growing interest in research in the field of assessment of tonus. However, the main focus of such research remains in spasticity and rigidity, resulting in an absence of studies involving hypotonia.



The scoping review also highlighted the lack of quantitative methods capable of assessing tonus from several muscles simultaneously and in real-time, since none of the selected papers discussed methods able to perform the assessment of more than one type of tonus, which reinforces the necessity of alternative methods of evaluation.

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**Author Contributions** ARR and CMA were responsible for searching the databases. IAM contributed in data extraction and compiling the studies selected from the search. ELMN and LAPSS contributed in the development of research ideas, coordinating the team and reviewing the results of the search. All authors contributed to the development of the manuscript and approved the final version.

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## Declarations

**Competing Interests** The authors declare that they have no conflict of interest.

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