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### SYSTEMATIC REVIEW

## Muscle Tone: General considerations. Review

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### ABSTRACT

#### Keywords:

Muscle tone;  
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Striated muscle;  
Diagnosis.

**Introduction:** The measurement of the muscle tone provides important information, in order to render the differential diagnosis, prognosis and treatment of the musculoskeletal and neuromuscular disorders. It can be considered as an important prognostic factor in the evolution of certain pathologies.

**Objective:** To perform an actualised description of the different examination methods of the muscle tone.

**Material and methods:** A bibliographic research was performed in databases such as PubMed (MEDLINE), Sciedirect (Scopus) and ISI Web of Knowledge, using terms like "muscle tone", "muscle tone", "stiffness", "measurement", "myotonometer", "reliability" and "validity", alone or combined.

**Results:** Systematic review trial, retrospective, with a sample of bibliographic analysis, including 52 articles (n=52) that satisfied the selection criteria carried out in two phases of analysis, which meant 8.9% of all founded articles (n=578) and 17.50% of the articles which fulfilled the selection criteria (n=297) (inclusion and exclusion). Measurement of specific muscular areas, such as tone, elasticity and stiffness, provide relevant information about the functional state of the muscle. The devices used nowadays for the quantification of the muscle tone are varied and of latest technology, but without forgetting the traditional manual tests and nominal scales, such as Asworth's.

**Conclusions:** The measurement of the muscle tone is an examination tool of great importance. The new devices that are used to examine muscle tone represent a forward step with regard to the traditional methods, since they are capable of measuring simultaneously three characteristics of the muscle, such as natural oscillation frequency, elasticity and stiffness.

## INTRODUCTION

Muscle tone is defined, from the clinical point of view, as the resistance to an external given strength, with the muscle in a voluntary relaxed state. Physically speaking, the resistance can also be explained like the increase of developed strength as a response to changes in the muscle length (muscular stiffness). One of the contributing factors to muscle tone is intrinsic stiffness, determined by the elastic and damping properties of the contractile device, as well as the inherent elasticity of the tendinous insertions and those of the muscle's connective tissue.<sup>1</sup>

Measurement of the muscle tone provides important information for the differential diagnosis, prognosis and treatment of the musculoskeletal and neuromuscular disorders. It can be considered an important prognostic for the evolution of certain pathologies.<sup>2</sup>

## MATERIAL AND METHODS

The bibliographic review was carried out using database such as PubMed (MEDLINE), Scencedirect (Scopus) and ISI Web of Knowledge. The terms used for the search were "muscle tone", "muscletonus", "stiffness", "measurement", "myotonometer", "reliability" and "validity", alone or combined one to another, considering the same until 2012, and for publishings written in English or Spanish.

### Selection criteria

Review was structured in two different phases of research. In the first phase, selection criteria were established (inclusion and exclusion) and in the second one, specific selection criteria were chosen.

Selection criteria. During phase 1 of the research, the following inclusion criteria were applied: articles published in scientific indexed magazines, in English or Spanish, related to every aspect concerning muscle tone and its evaluation in human beings.

During phase 2, selection criteria were applied to the chosen articles. The selection filter was made considering the title, summary, keywords, availability of the complete text and the bibliographic references of those articles included in phase 1 (figure1).

## Data analysis

Phase1.- First, a general search was carried out in order to obtain the published results related to the muscle tone and its evaluation.

A total of 578 studies were obtained (n=578), once the duplicated articles were discarded, to which criteria of inclusion and exclusion were applied, fact that allowed an initial selection of 297 articles (n=297) (figure 1).

Phase2.- Later, it was established the objective of reviewing all articles that regarded the relationship of the muscle tone with pain, the different devices used for measuring tone, as well as its reliability and validity. This way, a selection was made considering title, summary and keywords, which excluded 104 (n=104) initially selected articles. After that, a selection of the whole text was applied, which gave as result a final inclusion of 52 trials (n=52). Finally, an analysis of bibliographic references was made, to verify if there was feasible to obtain additional information, and it was not the case, so no complementary trial was obtained (n=0). For this reason, the sample of this trial consisted of 52 articles, selected according to PRISMA criteria for systematic reviews (figure1).

From all the magazines we have used in order to develop this review, we highlight two of them: Archives of Physical Medicine and Rehabilitation and Physiological Measurement, which with ten (n=10) and seven (n=7) results respectively, are the publishings that most articles bring to the subject of the trial.

## RESULTS

The sample of bibliographic analysis finally consisted of 52 articles (n=52), which fulfilled the selection criteria in two phases of analysis, which meant 8.9% of all founded articles and 17.50% of the articles that fulfilled the selection criteria (inclusion and exclusion).

In light of the performed search and once the different publishings were analysed with regard to the interest subject, the following aspects were emphasized, related to the muscle tone and their evaluation:

### Definition

Measurement of specific muscular properties, such as tone, elasticity and stiffness, contributes with relevant information on the functional state of the muscle. Evaluation of the skeletal muscle's properties is accepted clinically as a potential indicator of the effect of the applied treatment or the progression of the disease.<sup>3</sup>

Muscle tone, related to mechanical stiffness and elastical properties of the skeletal muscle, is considered as an essential factor in maintaining balance, stability and posture, since it allows an optimal postural control with energy efficiency.<sup>4</sup> Moreover, muscle tone is responsible for assuring an efficient muscular contraction in a static position, with no voluntary contraction.<sup>5</sup>

Between the mechanisms that contribute to maintaining muscle tone, we include reflex excitability, viscoelastic properties of the musculotendinous unity and intrinsic properties of the contractile elements.<sup>6</sup>

In literature, we can find different definitions related to muscle tone, such as the following: "passive muscular tension, as consequence of the intrinsic viscoelastic properties of the muscle with no contractile activity"<sup>4, 5</sup>, "resistance to passive stretching that reflexes the relative influences of the mechanoelastic muscular properties"<sup>7</sup>; "resistance to passive stretching, as a result of several mechanisms such as reflex excitability, mechanical properties of the musculotendinous unity (viscoelasticity) and intrinsic properties or active resistance to contractile elements";<sup>8</sup> "interaction between the muscle's viscoelastic properties, structures and neural regulation."<sup>9</sup>

### Variations of the muscle tone

The increase of muscle tone (which is described in literature as "stiffness") is a frequent circumstance in musculoskeletal disorders, being its normalisation one of the most important goals of the osteopathic treatment.<sup>10</sup>

Muscular hardness or stiffness represents an objective parameter which is defined as the degree of muscular deformity at a given pressure. From a technical point of view, stiffness or muscular hardness

is the mean of exchange rate in strength to change in length towards the main axis of the muscle.<sup>11</sup>

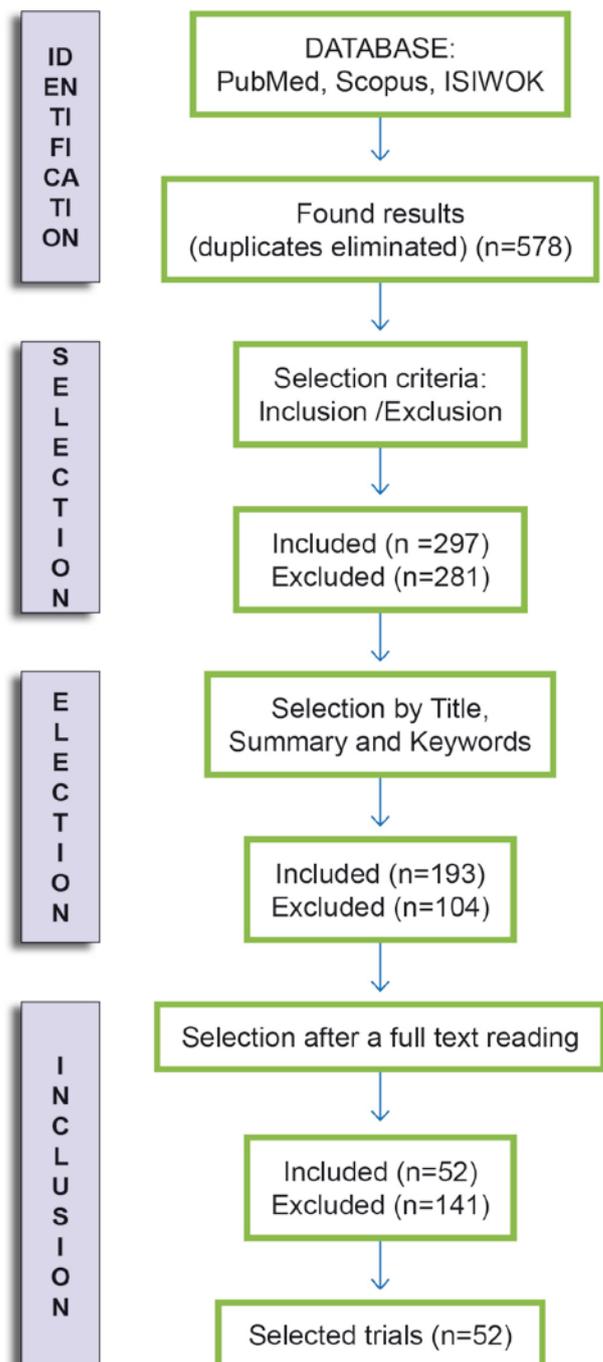


Figure1.- Flow chart of the articles' selection, according to PRISMA declaration for systematic review reports and meta-analysis for healthcare trials.

Moreover, this muscular hardness increases as the contraction progresses, being affected by muscular alterations and according to trigger levels.<sup>12</sup> For example, patients with syndrome of myofascial pain

have trigger points with tissue stiffness, feeling a tight band when palpating. Although chronic pathologies may induce physical changes in the muscle, causing it more stiffness when palpating, in general the increased muscular hardness is clinically associated with a neural activation of the muscle.

As an exception, we will mention the study of Andersen et al., in which when evaluating the trigger points of the trapezium through algometry, two of them revealed a low threshold under pressure (coinciding with typical locations for tender points or latent trigger points). However, these were the least stiffened areas with regard to the rest.<sup>13</sup> In any case, a palpable change in muscular stiffness produced in one day, one week or one month should be seen as a change in the amount of tension that the muscle exerts constantly.<sup>14</sup> This muscular hardness seems to depend of the muscular tension in the majority of the length ranges.<sup>15</sup>

Thus, the increase of muscle tone over normal conditions induces a sequence of alterations, such as muscular venous compression and alteration of the intramuscular movement, decreasing the volume of carried oxygen, which entails a painful state and damage of the motor function.<sup>15</sup>

Stiffness or hardness of the articular passive structures contributes very few to their mechanical stability, except for the last degrees of the range of motion. However, several trials determined that muscular properties of active stiffness are essential for dynamic stability. Optimal levels of musculotendinous stiffness are widely related to the significant improvements of the muscular function. This increase of the articular stiffness could limit the translation suffered at the articular level after an injury.<sup>16</sup>

There are some circumstances which can cause a pathologic increase in muscle tone. On the one side, we have the changes in mechanical and viscoelastic properties of the complex joint-tendon-muscle. On the other side, there are neurophysiologic alterations resulted from the activity of alfa motoneuron and/or disorders resulted from the local activity of the muscle spindles or gamma motoneurons. Between the last ones, there may be included an alteration of presynaptic inhibition, an inhibition of Renshaw's interneuron and disorders of neuroplastic adaptation or

hyperreflexia resulting from hypersensitivity to the sense of touch.<sup>9</sup>

Different trials have proven that muscle mechanical properties suffer alterations in certain neuromuscular pathologies, such as hyperthyroidism, Duchenne's muscular dystrophy, multiple sclerosis, spasticity or myofascial pain syndrome.<sup>17</sup> For example, abnormalities in muscle stiffness are a characteristic aspect of a sequence of neurological alterations, and in other painful syndromes, they are related to repeated, sportive or occupational traumatism.<sup>18</sup>

The used nomenclature for this pathologic muscular state varies, including terms such as "hypertonia", "stiffness", "hardness", "elasticity properties" and "viscoelasticity".<sup>10</sup>

### Measurement of muscle tone

Measurement of muscle tone is considered one of the most common used methods in clinical practice as evaluator and prognostic factor.<sup>1</sup>

Evaluating muscle tone through direct palpation and resistance represents one of the most common methods to determine the muscular state in clinical practice. However, tone evaluations used nowadays are based on manual methods, which use ambiguous register scales that depend more of the examiner's experience and subjectivity, so results can only be obtained using an ordinal scale. We must mention that for some authors, so far, manual palpation is the most important and precise method according to their experience, although they have a lack of objectives proves.<sup>19</sup> Clinical tests are like a prototype of this type of examinations, since they apply an ordinal scale to the resistance perceived by the examiner during a passive movement of the tested joint. A classic example of these types of tests is Asworth's scale and modified Asworth's scale, which basically evaluate the muscular tone and progressive stiffness.<sup>20, 21</sup> We must point out that even if the spasticity degree has been basically determined with this scale, new systems for its evaluation and for variations from the original scale are developed.<sup>22, 23</sup>

However, these measurements are not considered quantitative, since they do not own enough discriminative aspects, and the results are grouped in

few degrees.<sup>23</sup> This testing is not sensitive enough to detect small or moderate changes.<sup>2</sup> Moreover, its reliability is not clearly defined.<sup>20</sup>

On the other hand, classic evaluation methods of the muscle mechanical properties imply the use of specific experimental devices, designed for a specific joint. As a result, changes in different muscles' properties more or less affected by a specific pathology cannot be easily determined using the same procedure.<sup>17</sup> Moreover, measuring stiffness requires that the evaluated participants must make voluntary isometric contractions, maximum and submaximum, which can be painful and hard to carry out. We are talking about objective measurements that determine resistance to the present passive articular movement, while the evaluated limb moves under gravitational control or through an isokinetic dynamometer; an example of this type of measurements is Wartenberg's sign or pendulum test, developed by this author firstly in 1951 for examining the knee joint. This system, although objective and reliable, has a limited use for certain muscle groups, such as in the case of quadriceps, and besides that, it only provides one force, the gravitational one. In order to carry out this test, the patient must be in a relaxed position, on the edge of the examination table, with his/her legs stretched out. The examiner lifts both of his/her legs until the horizontal position, and then drops them observing their oscillation, which will be different depending on the muscle, if healthy or spastic.<sup>24-26</sup>

Another measurement system founded in the bibliography is the magnetic resonance elastography, which specifies the measure of stiffness from the muscle tissues.<sup>17</sup> This technique has been used to evaluate the mechanical properties of the pathologic muscles in rest position. However, this system has different limitations that restrict its clinical use, mostly due to its complexity and cost. Also, certain trials limit its capacity to detect small structural changes in time. Progression in this last device can be observed in the supersonic shear imaging device that solves partially these problems; its reliability has been proved.<sup>17</sup>

Other researchers have developed another device more quantifier for the tone, the "twister". This device studies tone regulation from the axial and proximal muscles, while maintaining an active posture. The

twister rotates axial areas of the body with regard to others rotating around a vertical axis. This rotation imposes length changes in axial muscles, without producing any change in the relation between body and gravity action. This system can be reconfigured in order to study several aspects of the muscle tone, such as co-contraction, tonic modulation with postural changes, tonic interactions through body segments, as well as perceptive thresholds to slow axial rotation.<sup>27</sup>

In the reviewed literature, there is a remarkable amount of articles centred in quantifying muscle tone through devices that study change in muscular hardness or stiffness, as a consequence of the applied forces through the axis of a given muscle. Several trials have proven that this force perpendicularly applied is proportional to the changes in muscular hardness.<sup>28, 29</sup>

All mentioned devices measure the movement of a certain muscle to which a compressive strength was applied perpendicularly. The most relevant example of this type of devices is the Myotonometer®.<sup>30</sup>

The Myotonometer® is an electronic device that has been developed since 1993, whose most important function is to measure the force-displacement characteristics of the muscle and other tissues located beneath the measuring probe or the area under the curve (AUC). This means that it provides an evaluation of the muscular hardness at rest and during the contraction. Measurements are obtained when quantifying resistance (measured in millimetres of tissue displacement) by unit of a force applied perpendicular to the tissue. Myotonometer® is formed by an inner metal probe (1 cm of diameter), surrounded by a plexiglass collar of 3.5 cm of diameter. Inside the probe, there are several transducers that monitor the applied downward pressure. Measurements are carried out in intervals of 0.25Kg, since 0.25 until 2.0Kg. Maximum applied force can be reduced to 1kg in special cases (when dealing with children or in very painful situations). Probe sends the information concerning force and tissue displacement to the computer connected to the Myotonometer®. The examiner pressures gently downward and perpendicular to the muscle. It must be considered the fact that applying an external compression it increases the tissue's stiffness.<sup>31</sup> While the pressure is applied, the probe dips into the muscle. As muscle tone is greater, less deepness is produced

by unity of strength, in such way that a contracted muscle will allow less deepness than when relaxed.<sup>30</sup>

Obtained measurements with Myotonometer<sup>®</sup> during a muscle contraction provide an indirect but valid measure of the muscle force<sup>18, 32</sup>, since muscular hardness or stiffness increases proportionally to muscle activation and torque production.<sup>33</sup>

Values in rest position give an exact determination of the muscle tone and the muscle compliance. This is possible because a muscle fibre gets stiffer when stimulated.<sup>29, 34</sup>

The use of Myotonometer<sup>®</sup> has certain advantages compared to surface electromyography (EMG), isokinetic test and dynamometer. The isokinetic and dynamometric tests can be influenced by muscular compensations and they only measure the joint torque, and not the muscle's contributions to the joint torque.

On the contrary, time for setting up the Myotonometer<sup>®</sup> is minimal and data can be obtained and interpreted quickly.<sup>30</sup>

Measurements of muscular stiffness made with Myotonometer<sup>®</sup> show an increase approximately linear with the increase of electromyographic measures of the muscle activation and contractile strength during the voluntary isometric contraction, indicating the tissue displacement during contractile conditions, which provides an indirect measurement of the muscle force.<sup>35</sup>

Clinical trials have proven that measurements provided by this device can distinguish between injured and not injured muscles, even years later after the injury, as well as quantify muscular imbalances.<sup>36</sup> Also, the Myotonometer<sup>®</sup> can quantify differences between subjects with alterations of the superior motoneuron and subjects without alterations, apart from distinguishing between homolateral and contralateral extremities to the injury.<sup>7</sup> Coon et al.<sup>37</sup> evaluated the effects of the manual technique of contraction-relaxation (in supine position) on the altered sensitivity and hardness (through Myotonometer<sup>®</sup>), at the level of the trapezium in subjects with cervical pain compared to healthy controls. There was a significant decrease of muscle hardness in the group whom received manual technique, although it was not very different from the result obtained by the control group. Moreover, it has been used

to measure the viscoelastic parameters for the muscles of triathletes<sup>38</sup>, as well as to determine the possible relation between the changes of passive hardness of the brachial biceps after eccentric exercise.<sup>39</sup>

Leonard et al.<sup>40</sup> found the correlation between the measurements of muscular hardness obtained with the Myotonometer<sup>®</sup> and the surface EMG during several degrees of voluntary isometric contraction of the brachial biceps. Data were obtained in rest position, with the subject holding 6.8Kg ballast, during a maximum voluntary isometric contraction. Measurements obtained with both instruments (AUC with Myotonometer<sup>®</sup>) had correlation, especially between 1 and 2 kg.

Gubler-Hanna et al.<sup>30</sup> followed the same line of research, concluding that the obtained measurements with the Myotonometer<sup>®</sup> proved a significant correlation with surface EMG and the production of knee-extensor torque during an isometric contraction.

Ditto et al.<sup>41</sup> proved the effectiveness of Myotonometer by finding changes in muscle compliance during a four-week programme of stretching for the calf muscle.

Myotonometer's reliability and validity<sup>7, 42, 43</sup> have been proven, verified in muscle tone's determination of children with PCI<sup>44</sup>, and also in muscle properties after rehabilitation in subjects with stroke.<sup>6</sup>

Other very similar devices have been used for determining muscle tone, as for the case of Myoton. This is a device that provides objective measurements of three muscular mechanical properties: tone, hardness and elasticity. Frequency of oscillation indicates muscle's tone in rest position. The logarithmic decrease of a muscle's natural oscillation indicates its elasticity or capacity to recover its shape after contraction. Dynamic stiffness (N/m) describes the muscle's resistance to contraction. There are several prototypes of Myoton, and the most frequent are Myoton-2 and Myoton-3, apart from the Myoton-Pro. The difference between the last device and the others is that this one has several updates, like a triaxial accelerometer, which makes it more versatile in terms of implementation.<sup>45</sup> Its reliability has been proved in the measurement of quadriceps' tone in healthy elderly patients.<sup>45</sup> Myoton-2 can be used to make measurements in the live image, simultaneously and in

non-invasive manner, of three parameters: natural oscillation frequency, which defines muscular tension, stiffness, like muscle's capacity to handle changes in shape, and the logarithmic decrease of muscle elasticity, meaning muscle's capacity to recover its initial shape after the co-contraction and/or deformity caused by external forces. Myoton-2 demonstrated a great reliability in measuring skeletal muscle's properties.<sup>5, 18</sup> Moreover, it has been proved that measurements made by this device are more precise and sensitive if compared to the others, obtained through a nominal scale in subjects with spasticity.<sup>46</sup>

As an example of the use of Myoton-3 (Myometry AS; Tallinn, Estonia), we must point out its use for objectifying the degree of passive muscular stiffness in patients with Parkinson, greater than in healthy controls.<sup>47</sup> This discovery matches previous studies, such as Watts'<sup>48</sup>, which concluded similar issues by using dynamometry and electromyography. In the same line of research, it has been determined that the increase of stiffness observed in patients with Parkinson is associated to values of hardness or viscoelastic stiffness.<sup>3</sup> In addition, it is recommended the use of myometry for diagnosis and for monitoring the effectiveness of the therapy of deep brain stimulation. Through the use of myometry, it is concluded that antiparkinsonian medication reduces not only the pathognomonic stiffness of this pathology, but also the hardness related to muscle stiffness in rest position. According to these authors, myometry can be added to the neurological practice, since it provides an objective and reliable vision of the treatment for parkinsonian stiffness.<sup>49</sup> Its reliability and validity have been proved when quantifying muscle tone, elasticity and hardness of the brachial biceps and triceps in patients with subacute CVA,<sup>4, 35</sup> as well as when determining quadriceps' stiffness of hardness.<sup>16</sup>

Jarocka et al.<sup>10</sup> compared measurements of tone and hardness of the brachioradial is muscle, using these two devices, Myoton-3 and Myotonometer®. Muscle skeletal's state was shown through the stiffness parameters of Myoton-3 (N m-1), frequency, as well as through the AUC of the Myotonometer®, with the muscle at rest and at 25%, 50%, 80% and 100% of voluntary maximum contraction in the elbow's flexor muscles.

When comparing both results separately, the degree of correlation between both measurements depended on if the evaluated muscle was at rest or in contraction and besides, it varied between different parameters. One last device related to muscle tone's evaluation is the tonometer (Medirehabook Ltd, Muurame, Finland), which quantifies the amount of muscle tissue displaced by the unity of force applied through a probe that is pressured against the tissue.<sup>50</sup> This device reads directly the muscle tone in normal conditions, and it can be used for diagnosis and treatment, motivating visual feedback.<sup>50</sup> Its reliability has also been proved.<sup>2</sup>

Finally, we point out the devices created to quantify muscular tension.<sup>51, 52</sup> For example, Đorđević et al.<sup>52</sup> are capable of measuring muscular tension through a sensor, using an innovating method during muscular contractions. Sensor is fixed on the skin over the muscle, and the sensor tip pressures the skin and provokes a light bleeding. Immediately afterwards, it applies pressure over the muscle. In that precise moment is when the strength on the sensor tip is measured. This strength is directly proportional to muscular tension. Measurement is non-invasive and selective.

## DISCUSSION

From the reviewed literature, we can conclude that the quantification of muscle tone is a necessary tool when evaluating the muscular functional state, as well as for determining the effect of the applied treatment.<sup>2</sup> Muscle activity, muscle thickness and length must be taken into account when evaluating the muscle tone.<sup>9</sup>

Evaluating a specific muscle (fact that can suffer changes due to fatigue or to a pathologic process) is normally carried out through palpation. According to bibliography, this evaluation is subjective and unappropriated for a correct comparison of changes that can occur in different stages of the therapy, and according to different therapists. Myotonometry is proposed as a reliable tool to quantify the possible differences, as said before.<sup>40</sup>

Myotonometry is a useful system for supervising the mechanical changes of the muscles that depend on time, such as it occurs in case of chronic syndromes. The main difference between myometry and other way

of evaluating the muscle tone is that this one can measure three characteristics of the muscle simultaneously: frequency of natural oscillation, elasticity and stiffness. Disproportion between stiffness and elasticity of the muscle tissue in its altered process of contraction and relax is proposed as a new indicator of pathologic changes in tissues.<sup>5</sup>

Myotonometric measures represent a new and valid approximation for an indirect evaluation of the muscle force. Speed and ease in obtaining data and in analysing the founded results give this system a clear advantage over electromyography.

Between the advantages of dynamometry, the capacity to quantify changes in muscle compliance of isolated muscles is mentioned, during measurements of joint strength and not only total joint strength. Muscle replacements are not possible and neither are device's portability and easy handling.<sup>43</sup>

Another advantage of using Myoton and other devices is its capacity for measuring isolated muscles and also for avoiding co-contraction for antagonist muscles, which has a great influence on muscle stiffness.<sup>6</sup>

## CONCLUSIONS

From this systematic review, we can conclude that measuring the muscle tone represents a relevant evaluation tool, until the point of becoming a prognosis factor in the progression of certain pathologies. The new devices used for the quantification of the muscle tone represent a forward step with regard to the traditional methods of evaluation, since they are capable of measuring simultaneously three characteristics of the muscle, such as natural oscillation frequency, elasticity and stiffness. Moreover, these measurements obtained with devices such as the Myotonometer<sup>®</sup> represent a new valid approach to carry out an indirect evaluation of the muscle strength.

For all reasons exposed in the review many authors support the use of these devices and suggest to compare their reliability with the one obtained in the same participants in other classical measurements, such as the modified Asworth's scale.<sup>46</sup>

## CONFLICT OF INTEREST

Authors declare they had no conflict of interest.

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