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# Neurophysiological Assessment of H-Reflex Alterations in Compressive Radiculopathy

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**Summary**

This study aimed to investigate changes in the H-reflex recruitment curve in compressive radiculopathy, specifically assessing differences between symptomatic and asymptomatic limbs in patients with unilateral S1 radiculopathy through derived parameters. A total of 24 volunteers (15 male and 9 female, aged between 22 and 60 years) with confirmed nerve root compression in the L5/S1 segment participated. Nerve root compression was verified through clinical MRI examination and attributed to disc protrusion, spinal canal stenosis, or isthmic spondylolisthesis of L5/S1. Analysis revealed no difference in M-wave threshold intensity between symptomatic and non-symptomatic limbs. However, the H-reflex exhibited a trend toward increased threshold intensity in the symptomatic limb. Notably, a significant decrease in the slope of the H-reflex was observed on the symptomatic side, and the maximal H-reflex amplitude proved to be markedly different between the two limbs. The Hmax/Mmax ratio demonstrated a significant decrease in the symptomatic limb, indicating reduced effectiveness of signal translation. In conclusion, our findings emphasize the importance of H-reflex parameters in evaluating altered recruitment curves, offering valuable insights for neurological examinations. The observed differences in maximal values of M-wave, H-reflex, and their ratio in affected and unaffected limbs can enhance the diagnostic process for lumbosacral unilateral radiculopathy and contribute to a standardized approach in clinical assessments.

**Key words**

Radiculopathy • Electromyography • H-reflex • M-wave • Recruitment curve

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## Introduction

Low back pain (LBP) stands as the most prevalent musculoskeletal condition globally and represents the foremost cause of disability on a worldwide scale [1,2]. LBP is a common issue in primary care, with most primary care physicians anticipating at least one patient presenting with low back pain per week. While acute episodes of back pain are typically self-limited, individuals experiencing persistent or fluctuating pain lasting beyond three months are categorized as having chronic low back pain. Chronic LBP significantly contributes to work loss, participation restrictions, and diminished quality of life globally, thereby imposing a substantial economic burden on societies. Recognizing its high prevalence, LBP should be acknowledged as a global public health concern necessitating an appropriate response. The economic impact of chronic low back pain results from prolonged

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functional impairment, leading to reduced work productivity, treatment costs, and disability payments. Estimates of these costs range from $12.2 to $90.6 billion annually [3].

In contrast to chronic low back pain, acute forms of low back pain are as common, usually following a bending or twisting spine movement or a high back strain, but might sometimes be related to neurological causes instead [4]. In order to differentiate the gravity of the acute low back pain, a thorough evaluation needs to be undertaken to respect the possibility of more concerning syndromes, such as radiculopathy. This syndrome tends to manifest with a distinct set of neurologically oriented symptoms, including radiating pain, muscle weakness in the affected lower limb, and paresthesia [5]. However, in the early stages, it poses a challenge to the examiner due to its resemblance to the more prevalent acute low back strain, which typically lacks clear neurological symptoms [4]. While magnetic resonance or computer tomography is usually considered the gold standard for spine examination, many patients may exhibit clinically unrelated or "silent" findings on diagnostic imaging, potentially leading to false positive results [6]. Electrophysiology assessments utilizing needle electromyography (EMG), which primarily evaluate ventral root function, may yield inconclusive or false negative results [5]. The need for a specific set of diagnostic criteria, achieved by a collection of neurological tests and diagnostic imaging, is also required due to the serious nature of radiculopathy. Not only the set of related symptoms, including muscle weakness and a sharp, intense lower limb and low back pain, hinders patient's quality of life significantly, but the chance of spontaneous recovery and the overall prognosis is far less positive in the case of radiculopathy compared to an acute low back sprain [4].

The H-reflex, named after P. Hoffman, represents a reflexive response recorded by surface electrodes from the muscle following electric stimulation of the supplying peripheral nerve. As most excitable Ia afferent fibers are highly susceptible to compression or ischemia-induced effects [7], a significant increase in the threshold for the H-reflex is anticipated [8]. Such an increase in H-threshold may constitute the earliest abnormality even in the absence of focal neurological signs. We hypothesize that by eliciting the reflective response of the H-reflex, differences in threshold, latency, or amplitude may be observed between the symptomatic and asymptomatic lower limbs [9]. When combined with an absence of other central or peripheral nerve lesions, potential abnormalities in the elicited response may indicate an injury at the root level.

The primary objective of this study was to elucidate alterations in the H-reflex recruitment curve in compressive radiculopathy and assess its derived parameters. These parameters hold promise for aiding in the early differential diagnostic process of low back pain.

## Methods

24 volunteers were recruited for the study (15 male and 9 female, with an age range between 22 and 60 years). All participants signed a written consent and the study was approved by the Ethics Committee at the Faculty of Physical Education and Sport, Charles University (No. 0180/2010).

The inclusion criteria included unilateral S1 radicular syndrome lasting for less than 6 months, muscle strength of level 4 or above as measured by the muscle testing and absence of sensory or sphincter deficit. There was a nerve root compression present in the L5/S1 segment caused by a disc protrusion, spinal canal stenosis, or isthmic spondylolistesis of L5/S1, verified by a clinical MRI examination. Each proband had to pass a clinical neurological examination and clinical electrophysiological examinations of motor conduction of the n. peroneus and n. tibialis, sensory conduction of the n. suralis, F-wave for the m. extenzor digitorum brevis and abductor hallucis bilaterally and needle EMG on the symptomatic side in the L5 and S1 segments with the search for denervation phenomena and analysis of motor units. The exclusion criteria included metabolic diseases, neuromuscular diseases such as myelopathy, or any previous trauma or surgery related to spine or lower limbs.

During the test protocol, participants were asked to lie prone with a pillow placed under the ankle to increase the relaxation of lower limb muscles. The skin was cleaned with an alcohol swab and a bipolar percutaneous stimulation electrode was placed bilaterally in the popliteal fossa and attached with a velcro brace. Two surface Ag-AgCl electrodes (Medtronic, Minneapolis, USA) were placed on the soleus muscle to obtain the H-reflex and M-wave. All the electrophysiological procedures were performed by a four-channel computer-based EMG unit Neuropack 8 MEB 4200k (Nihon Kohden, Tokyo, Japan). By adjusting the position of the stimulating electrode (cathode being proximal), the location with the lowest threshold for the H-reflex was identified. With a frequency of 0.1 Hz a monophasic rectangular constant current 0.5 ms long stimulus was applied with intensities increasing in steps of 0.4 mA until the maximum H-reflex amplitude was obtained and further in steps of 0.8 mA until the maximum M-wave was reached.

The following parameters were measured: M-wave and H-reflex thresholds and amplitudes, slopes of recruitment curves, maximal M-wave and H-reflex values (Mmax and Hmax, respectively) and the Hmax to Mmax ratio. Data were processed using Matlab software (Mathworks, Nattick, USA) with signal processing toolbox and custom written scripts.

For the statistical analysis, the normality of data was checked using the Shapiro-Wilk test, while the comparison of sides was done using a paired *t*-test. Data is shown as mean ± Standard Error of Mean (SEM). Statistical significance of the test was set to P=0.05.

## Results

In all patients H-reflex and M-wave were successfully elicited and responses allowed to construct and analyze individual recruitment curves and derived desired parameters. Significant differences were found in a number of key components of the elicited responses, albeit not in all of them (overview is in Table 1). First, we evaluated the threshold stimulation intensity for M-wave and H-reflex which corresponds to the minimum stimulus strength required to elicit a registerable response (M-wave). We evaluated both the absolute [mA] and the normalized [to Mmax] stimulation intensities. We observed no difference in M-wave threshold intensity (P=0.242) between symptomatic limb (11.531±1.294 mA) compared to the non-symptomatic limb (9.922±0.883 mA), Figure 1. H-reflex exhibited trend to an increase (P=0.085) of threshold intensity between symptomatic (12.727±1.986) compared non-symptomatic (8.845±1.129) limb when compared in absolute and also normalized values, Figure 2. Although slope of the M-wave did not differ between the limbs, a significant decrease (P<0.01) in slope of the H-reflex has been observed on symptomatic side (42.914±6.252) compared to non-symptomatic (60.228±5.329), Figure 3. The maximal H-reflex amplitude (Fig. 4) proved to be the most different between the symptomatic and the asymptomatic lower limb (4.193±0.965 and 9.365±1.350 respectively, P<0.001). This parameter represents the number of motoneurons responsive to the stimulation, or, in other words, Hmax is a measure of maximal reflex activation of a given muscle. Complementary to this finding is the difference in the maximal M-wave amplitude (Fig. 4), which represents activation of the entire motoneuron pool in the sensor's vicinity and, therefore, maximal achievable muscle activation. We found a significant difference between the symptomatic and asymptomatic limbs (17.081±1.492 and 22.802±1.893 respectively, P<0.05). The Hmax/Mmax ratio can then be derived to show the effectiveness of signal translation, or the proportion of the entire motoneuron pool capable of being recruited. In regard to this parameter, the symptomatic limb showed a significant decrease compared to the non-symptomatic limb (0.235±0.486 to 0.401±0.493 respectively, P<0.05), Figure 5. The latency H-reflex did not show a significant difference between the symptomatic and asymptomatic limbs in patients with unilateral S1 radiculopathy.

The recruitment curve on the asymptomatic limb represents a standard relation between the stimulus and the amplitude with a clear distinction between the peak and the endpoint, where the H-reflex disappears or M-wave reaches its maximum (Fig. 6). The symptomatic side presents itself with a smaller amplitude of the H-reflex in relation to the stimulus intensity, stressing the need to assess the quality of the curve when eliciting the H-reflex.

**Table 1.** Parameters obtained through the test protocol from the tibial nerve and soleus muscle respectively for the symptomatic and asymptomatic limb. Data is shown in mean ± SEM with Mmax and Hmax values in [mV], threshold in [mA], slope in degrees [°] and H-reflex latency in [ms]. Mmax – maximal M-wave amplitude, Hmax – maximal H-reflex amplitude.

| Parameter | Symptomatic | Non-symptomatic | P value | Significance |
|---|---|---|---|---|
| *Mmax* | 17.081 ± 1.492 | 22.802 ± 1.893 | <0.05 | **Significant** |
| *Hmax* | 4.193 ± 0.965 | 9.365 ± 1.350 | <0.001 | **Significant** |
| *M-wave threshold* | 0.286 ± 0.0225 | 0.267 ± 0.883 | 0.503 | Non-significant |
| *H-reflex threshold* | 0.310 ± 0.0423 | 0.236 ± 0.0271 | 0.074 | Non-significant |
| *M-wave slope* | 87.205 ± 0.504 | 87.127 ± 0.894 | 0.080 | Non-significant |
| *H-wave slope* | 42.914 ± 6.252 | 60.228 ± 5.329 | <0.01 | **Significant** |
| *Hmax/Mmax* | 0.235 ± 0.486 | 0.401 ± 0.493 | <0.05 | **Significant** |
| *H-reflex latency* | 32.06 ± 0.552 | 30.87 ± 0.469 | 0.1089 | Non-significant |

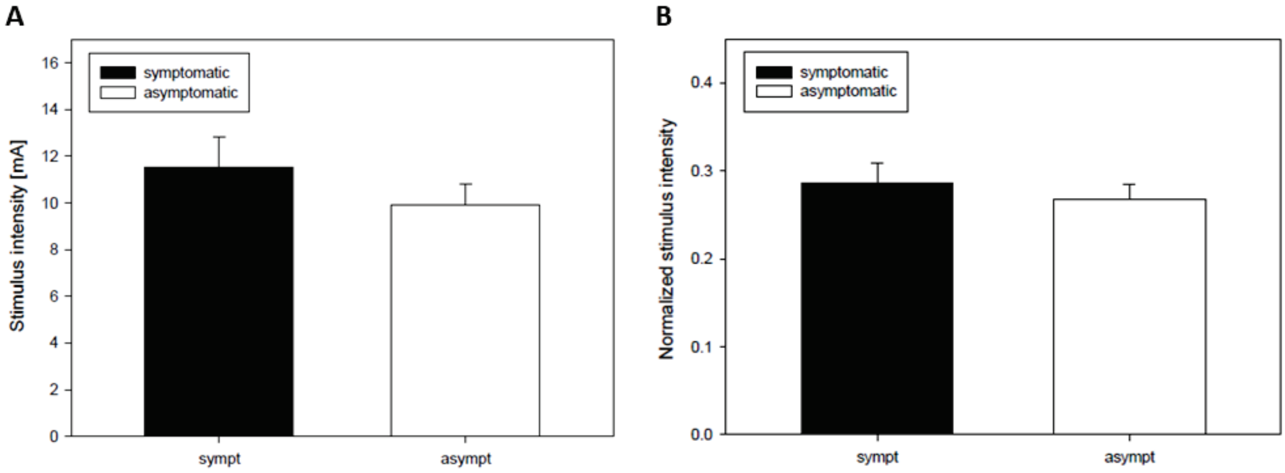


**Fig. 1.** M wave threshold stimulation intensities did not differ between the symptomatic and asymptomatic lower limbs. (**A**) Absolute [mA] nor normalized values to Mmax (Mmax=1), (**B**) Data shown as mean ± SEM.

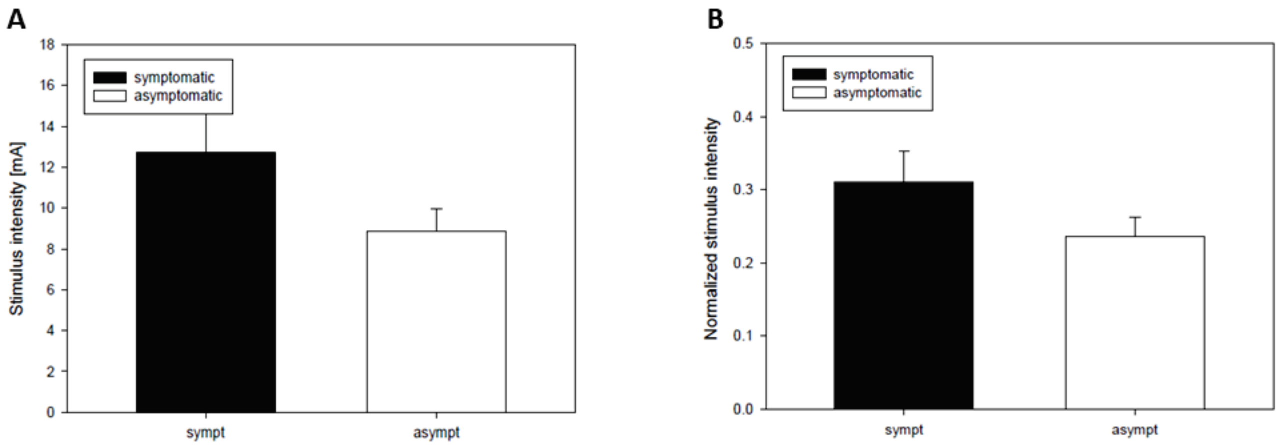


**Fig. 2.** H reflex threshold stimulation intensities did not differ between the symptomatic and asymptomatic lower limbs. (**A**) In absolute [mA] nor normalized values to Mmax (Mmax=1), (**B**) Data shown as mean ± SEM.

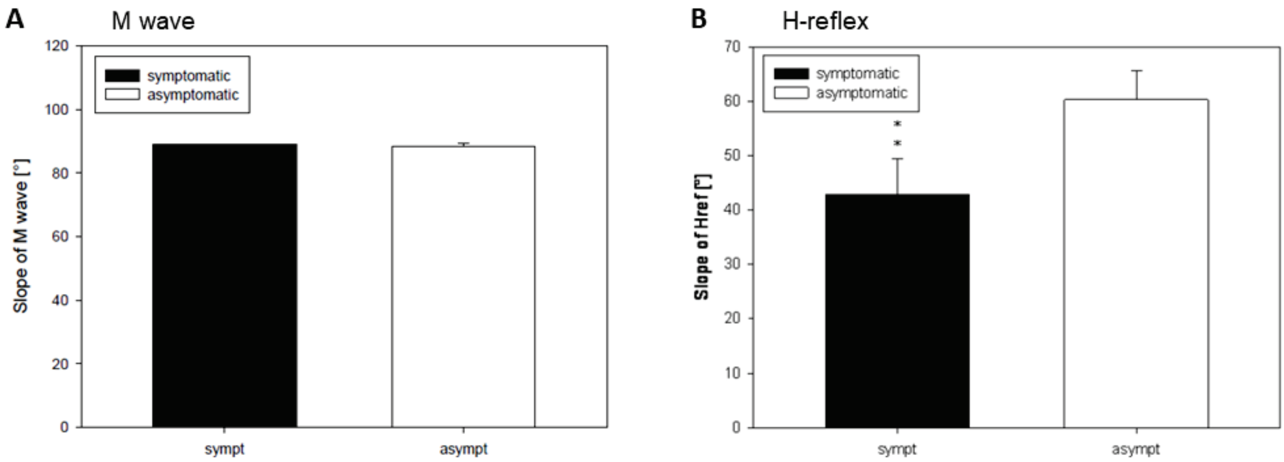


**Fig. 3.** The slope of the recruitment curve for M wave did not differ between the limbs (**A**), while a significant decrease in slope of the H reflex has been found suggesting altered excitability (**B**). Data shown as mean ± SEM.

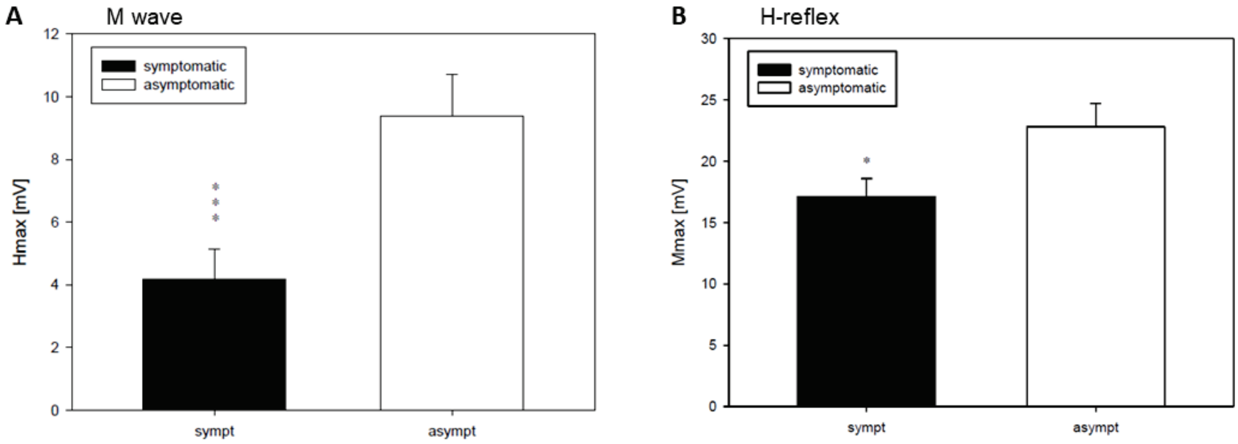


**Fig. 4.** Values of maximal amplitude compared for the symptomatic and asymptomatic lower limbs. (**A**) Maximal amplitude of the M-wave. (**B**) Maximal amplitude of the H-reflex. Data shown as mean ± SEM.

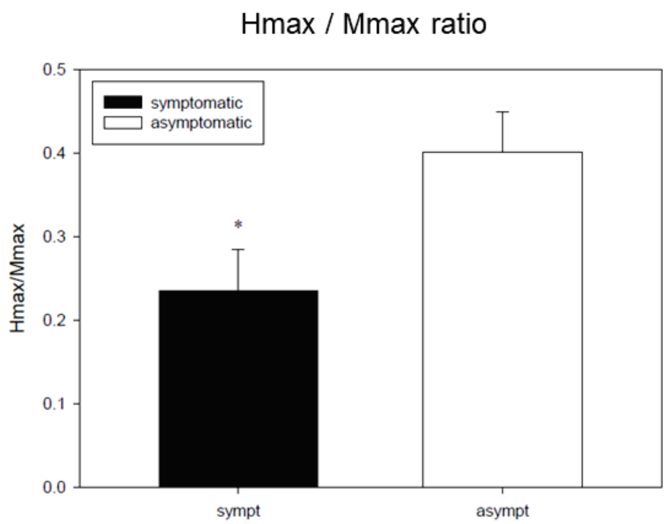


**Fig. 5**. The Hmax/Mmax assesses the effectiveness of signal translation, or the proportion of the entire motoneuron pool capable of being recruited. In regard to this parameter, the symptomatic limb showed a significant decrease compared to the non-symptomatic limb. Data shown as mean ± SEM.

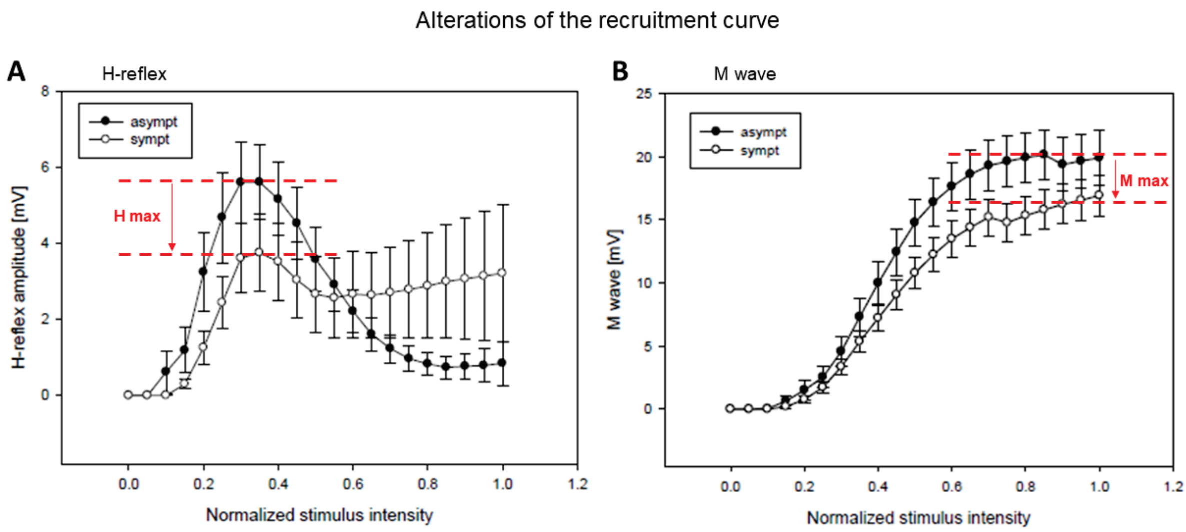


**Fig. 6.** The recruitment curves of H-reflex (**A**) and M wave (**B**) for both the symptomatic and asymptomatic limbs. Highlighted are the main points of difference, showing the discrepancy of amplitude in the symptomatic limb compared to a normal curve, represented by the unaffected limb. Data shown as mean ± SEM.

## Discussion

The aim of this study was to elucidate alterations in the H-reflex recruitment curve in compressive radiculopathy and evaluate the difference between the symptomatic and asymptomatic limbs in patients with unilateral S1 radiculopathy by derived parameters. Our findings further solidify the impact of electrophysiological examination in the presence of neurological symptoms, especially those related to radiculopathy or other nerve root lesions of the lumbar spine. We have confirmed that recruitment curve of the evoked responses significantly differs on the symptomatic side and is highly sensitive approach as suggested previously [5,9]. However, it should be emphasized, that in routine neurological clinical practice is acquisition and analysis of the whole recruitment demanding to almost impossible. Thus, we have tested several parameters derived from the recruitment curve which can also be assessed more easily in general setting and hopefully provide similar information about functional alterations of affected peripheral nerve.

After eliciting the H-reflex, we were able to observe the changes in amplitude, latency, recruitment thresholds and slopes for both the symptomatic and asymptomatic limbs in patients with unilateral S1 radiculopathy. The difference in maximal amplitude of the H-reflex (marked as the Hmax in Fig. 4) between the affected and unaffected limbs was the most significant one in our study. This finding further shows the effect of nerve root compression on the neuromuscular system, limiting the number of motoneurons responsible to the stimulation. In relation to the changes in Mmax, the more prominent discrepancy in Hmax can support the notion of different sensitivity of sensory fibers, which would prove to be more susceptible to most causes of nerve root compression or ischemia [9,10]. Ischemia specifically can play an important role in the changes observed in the sensory fibers due to its effect on threshold channels. Effects of ischemia were shown to first impact the sensory fibers, inducing paresthesia before fasciculations or other features related to motor fibers [10]. This would possibly increase the diagnostic value of both the Hmax and Hmax/Mmax ratio in the process of an early examination in patients with high suspicion for radiculopathy, where only the sensory fibers might be compromised [3,11].

To underline these findings, the recruitment curve of the H-reflex describes a clear distinction in the nerve response to the stimulation, as mentioned before. The symptomatic side responds to a similar stimulus intensity with a lower amplitude, resulting in a lower peak of the H-reflex and a different curve (Fig. 6). The asymptomatic limb then represents a standard increase in amplitude in response to increased stimulus intensity, progressing to the disappearance of the H-reflex [12].

The maximal amplitude of the M-wave, marked as the Mmax in the Figure 4, reflects the number of motor units activated during the stimulation of the tibial nerve. With a significant difference, the symptomatic soleus muscle was able to provide a smaller motor response to the same stimulation as the asymptomatic one (Fig. 6). This difference can perhaps be explained by an axonal loss or a conduction block [13,14]. A time-dependance can be hypothesized, where prolonged or more pronounced radiculopathies could present themselves by a larger difference in the Mmax, representing the axonal degeneration process.

These results are in agreement with other work on this topic, where the decrease of H-reflex amplitude was also seen in the same population of patients [3,15]. In contrast to the amplitude, the latency of H-reflex did not reach a significant difference between the unaffected and affected limbs and proved to be more similar, especially in patients with earlier stages of radiculopathy, which corresponds with other work on this topic as well [15].

However, we feel the need to point out that finding an abnormality in the recruitment of the H-reflex or other underlying parameters does not by itself confirm a radiculopathy in given patient. Only in conjunction with other standard examination techniques such as MRI and appearance of clinical symptoms can lead to increased diagnostic sensitivity [3].

Our study aimed to provide a better insight into the role of H-reflex, its parameters, and subsequent changes in the diagnostic process for unilateral compressive radiculopathy. We conclude that the maximal values of the M-wave, H-reflex, and their ratio in the affected and unaffected limb of a patient with lumbosacral unilateral radiculopathy offer a reliable evaluation of major patterns in the altered recruitment curve. These findings provide valuable insights for neurological examinations and should be considered as part of the standardized diagnostic process.

## Conflict of Interest

There is no conflict of interest.

## Acknowledgements

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