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Modified Ashworth Scale and Alpha Motor Neuron Excitability Indicators of F-wave in Spastic Soleus Muscle Early after Stroke

Abhijeet Toshniwal[1], Abraham M. Joshua[1] and S. Karthikbabu[2*]

[1]Department of Physiotherapy, Kasturba Medical College, Manipal University, Mangalore, India.
[2]Department of Physiotherapy, School of Allied Health Sciences, Manipal University, Manipal Hospital, Bangalore, India.

Authors' contributions

This work was carried out in collaboration between all authors. Author AT wrote the protocol, administered the MAS and collected the data. Author AMJ specified the research question and managed the study process. Author SK designed the study, wrote the first draft of the manuscript, analyzed the data and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Plantar flexor spasticity affects walking ability after stroke. Spasticity is clinically tested by modified Ashworth Scale (MAS) and it is fairly reliable. The aim of this study was to test the correlation between MAS and alpha motor neuron excitability indicators of F-wave in spastic soleus muscles early after stroke.
Place and Duration of Study: Neurophysiology laboratory, Kasturba Medical College, Mangalore, India and between June 2010- August 2012.
Methodology: Twenty three people with post stroke duration of 2.26 (1.18) months and MAS score > 1 on soleus muscle participated in this cross-sectional study. Modified Ashworth Scale and F-wave procedures were administered on spastic soleus muscle and the relationship was tested by Spearman's rank correlation coefficient.
Results: The correlation of MAS to persistence of F-wave was high (r=0.842; p=<0.0001), but not

**Corresponding author: E-mail: karthikbabu78@gmail.com;*

with latency of F-wave (r= -0.264; p=0.223). A moderate correlation was found for post stoke duration to F-wave persistence (r=0.45; p=0.013) and the relation was nonlinear with latency of F-wave (r=0.016; p=0.950).

Conclusion: Modified Ashworth scale may be a tool to measure the neural aspects of soleus muscle spasticity i.e. alpha motor neuron excitability in people with early stage stroke.

Keywords: Modified ashworth scale; F-wave; spasticity; stroke.

1. INTRODUCTION

Spasticity is present in 43% of patients after stroke [1], and plantar flexor spasticity is the major impairment contributing to the poor walking performance [2]. It is a motor disorder characterized by a velocity dependent increase in tonic stretch reflexes with exaggerated tendon jerks resulting from hyper-excitability of the stretch reflex as one component of the upper motor neuron syndrome. It is associated with various neuro physiological changes in the segmental spinal circuitry including increased excitability of the alpha motor neurons, decreased pre-synaptic and reciprocal inhibition along with reduced I A facilitation [3,4]. It is believed that this reflex-mediated altered muscular tone reaches to maximum during the initial 3-4 months duration post stroke [5]. The severity of muscle spasticity is graded using Modified Ashworth Scale (MAS) [4] and the scale is found to be fairly reliable [6,7].

The late response studies like Hoffman's reflex (H reflex), F-waves and their variants were the electrophysiological tests to measure the degree of alpha motor neuron excitability in spastic muscles. Hoffmann's reflex when correlated to clinically observed increase in the myotatic stretch reflex activity could discriminate spasticity to normal muscle tone [8]. Bakheit et al. [4] evaluated the excitability of the alpha motor neurons by measuring the latency of H reflex and the ratio between the maximum amplitude of H reflex (H-max) and compound action motor potential of the soleus muscle (M-max). The observed increased H-max:M-max ratio and reduced H reflex latency in people with MAS grade 1 and 2. Whereas, the values of H-max:M-max ratio were higher for people scoring grade 2 in MAS, but with no statistical differences. This work suggests that the MAS can be used as a measure of muscular hypertonia than spasticity. Ghotbi et al. [9] investigated the relationship between the MAS scores and alpha motor neuron excitability indicators (H latency) in ankle plantar flexors and suggested that the MAS could not differentiate the non-reflexive aspects of the muscular stiffness from reflexive hypertonicity.

In clinical practice, the usage of Modified Ashworth scale has a disadvantage of measuring the non-neural aspects of spasticity i.e. altered tissue viscoelastic properties of muscles. This poses a clinical situation where many of clinicians seem to prefer various manual test methods and clinical observations to assess the severity of spasticity. We believe that MAS may be the tool to assess the neural aspects of muscle spasticity as a measure of alpha motor neuron excitability in early recovery stage after stroke when severe tissue adaptation is not common. It is recognized that F-wave could be the potential means of measuring the excitability of the alpha motor neurons [10-12]. Amongst the various F-wave variables, minimal F-wave latency and persistence upon serial stimulation have been described as indicators of upper motor neuron dysfunction [13,14]. In this study, we aimed to conduct the F-wave test on spastic soleus muscle and attempted to correlate the severity of spasticity measured by MAS in people with early stage stroke. If linear relation was found, MAS can be considered as measurement of neural aspects of muscle spasticity i.e. alpha motor neuron excitability in people with early stage stroke.

2. METHODS

This cross-sectional study was conducted in neurophysiology laboratory, Kasturba Medical College Hospitals, Mangalore and was approved by Institutional Ethical Committee (IEC), Manipal University, India. People with stroke were contacted and screened for eligibility criteria. An informed consent was obtained from the volunteers seeking their participation in the study. People with first episode of hemorrhage or ischemic stroke lesion, less than four months post stroke duration, scoring ≥ 1 on MAS, brisk ankle deep tendon reflex were included in the study. Those diagnosed with peripheral neuropathy, deep vein thrombosis and restricted dorsiflexion movement due to musculoskeletal pathology, receive the antispastic drugs on the day of assessment, history of recent surgery to control muscle spasticity, pain during the measurement time were excluded from the study. All of them were undergoing physiotherapy treatment focusing on tone modulation exercises at the time of study participation. Modified Ashworth scale was administered by a qualified physical therapist while F-wave test was conducted by neurophysiologist for all the study participants. The order of tests was randomly selected from an opaque sealed envelope and was administered in soleus muscle.

Modified Ashworth Scale (MAS) is a five-point ordinal scale used for measuring muscle spasticity by grading the resistance encountered during passive muscle stretching [15]. To grade the soleus muscle spasticity, the person with stroke was positioned on side lying with hips and knees in 45 degrees of flexion. The tester stabilized the lower leg by holding proximal to ankle joint with one hand. The thumb and fingers of other hand was placed lateral and medial to foot with palm supporting the sole of foot and then the tester moved the ankle joint from maximal plantar flexion to maximal dorsiflexion. After three test movements, the tester graded the best resistance felt with a single score using MAS [6,15] (Figure 1).

Figure 1. Assessment of soleus muscle tone with modified Ashworth scale

F-wave is the late muscle response resulting from the antidromic activation of one or small number of motor and/or mixed peripheral neuron(s) following supra maximal stimulus [16]. Persistence and latency of F-wave were considered to measure the excitability of the alpha motor neuron pool at spinal cord. The persistence of F-wave was measured by the number of responses occurred upon the number of stimuli given. The latency of F-wave was calculated by measuring the time taken from the stimulus artifact to initial deflection of the F-wave. These parameters of F-wave were obtained from an EMG machine (Manf. Nihon Kohden Neuropack) using silver disc electrodes. Each patient was positioned on prone with feet out of the plinth and recording electrodes (E1& E2) were placed at the medial aspect of the soleus i.e. Gastroc-soleus junction and at Achilles tendon, respectively. A ground electrode was placed proximal between the stimulus and recording electrodes. Tibial nerve was stimulated at popliteal fossa with surface probe of cathode proximal to anode [17]. A total of eight supra-maximal stimulations were given using 'square wave' stimulator with 0.1 ms pulse duration (Figure 2).

Figure 2. F wave test procedure

2.1 Data Analysis

Statistical analysis was conducted using SPSS version 13.0 (SPSS. Inc). Spearman's rank correlation coefficient (r) was derived to analyze the relationship between the MAS score and F-wave persistence and latency. The 'r' is read as very high (0.80-1.00), high (0.60-0.79), moderate (0.40-0.59), low (0.20-0.39), and very low (<0.20). The p value of < 0.05 was statistically significant. We conducted regression analysis (r^2) to estimate or predict the causal relationships among a dependent or independent variables.

3. RESULTS

Twenty three people with stroke participated in this study. The mean (SD) age and post-stroke duration of the participants were 56.65 (12.9) years and 2.26 (1.18) months, respectively. On modified Ashworth grading, 10 of them had grade-1spasticity and eight had grade 1+ spasticity and five scored grade-2 on MAS. The mean percentage of F-wave persistence was 60 % and the latency was 46.94 (6.17) milliseconds.

We found MAS score was highly correlated to F wave persistence (r = 0.842; p = <0.0001), but not with F-wave latency (r = -0.264; p= 0.023). A low moderate correlation was observed between the post stroke duration and F-wave persistence (r=0.45; p= 0.013). And, the post stroke duration was shown a non-linear relationship to latency of F wave (r= 0.016; p= 0.950). Table 1 shows the demographic and clinical characteristics of the people with stroke.

A regression analysis showed that persistence of F wave had a significant correlation (r^2 = 0.672) with MAS, whereas latency of F-wave had weak correlation (r^2=0.069) stating that 67 percent of MAS score was dependent on the persistence of F-wave (Figures 3 and 4).

4. DISCUSSION

This study aimed to explore the correlation of MAS scores to the latency and persistence of F-wave, alpha motor neuron excitability indicators in soleus muscle for people with early stage stroke. A high correlation was found between MAS scores and persistence of F-wave and a moderate correlation between post stroke duration and persistence of F-wave. A nonlinear relationship was found for the latency of F-wave to MAS scores and duration after stroke. Estimation of seven to ten identifiable F-waves provides reasonable information on persistence [18] which reflects the excitability in the spinal motor neuronal pool [10]. Elevated excitability of spinal motor neurons due to Renshaw cell inhibition and reduced inhibitory control mechanisms could be the possible reasons for increased persistence of F wave in spastic muscle [10]. We observed an incremental percentile of F-wave persistence and the persistence was correlated to various grades of MAS and post stroke duration. The continuous stimulus from somatosensory structures and internal visceral organs could be the cause for rise in spasticity during initial 3-4 months after stroke. In the absence of cortical disinhibition resulting from post stroke, these stimuli give rise to increase in alpha motor neuron excitability at spinal neuronal pool. Naseri et al. [10] supports this view. Milanov [11] also believed that F-wave is a more sensitive measure to assess lower motor neuron excitability in comparison to soleus tendon reflex and H-reflex. Contrary, a weak correlation was reported between clinically observed increase in the myotatic stretch reflex activity measured by MAS and the degree of the alpha motor neuron excitability measured by H-reflex [4].

Table 1. Demographic and clinical characteristics of study participants

Sr. No	Age	Gender	Hemiplegic side	Post stroke duration (months)	MAS	Latency of F wave (millisecond)	Persistence of F wave (%)
1	65	F	R	1	1+	44.5	75
2	42	M	R	3	1	59.2	63
3	52	M	R	2	1+	43	63
4	66	F	R	2	1+	46.5	63
5	45	M	L	1	1	55	50
6	55	M	R	2	1+	49	63
7	75	M	L	1	1	35.9	25
8	48	M	R	4	1+	46.1	88
9	70	F	L	2	1	55.4	38
10	40	M	R	2	2	48.9	75
11	55	M	R	1	1+	47.8	63
12	75	M	R	1	1	50.5	25
13	42	M	L	4	2	40.9	100
14	54	M	R	1	1	47.9	38
15	65	M	R	2	1	51.9	50
16	59	M	R	2	2	42.2	63
17	53	F	R	4	1+	41.7	63
18	75	F	L	4	1	46.1	13
19	50	M	R	1	1	33.1	50
20	28	M	L	2	2	38.9	100
21	52	M	R	4	2	52.8	75
22	45	M	R	4	1+	44.6	88
23	92	F	R	2	1	49.7	50

F-female; M-male; R-right; L-left

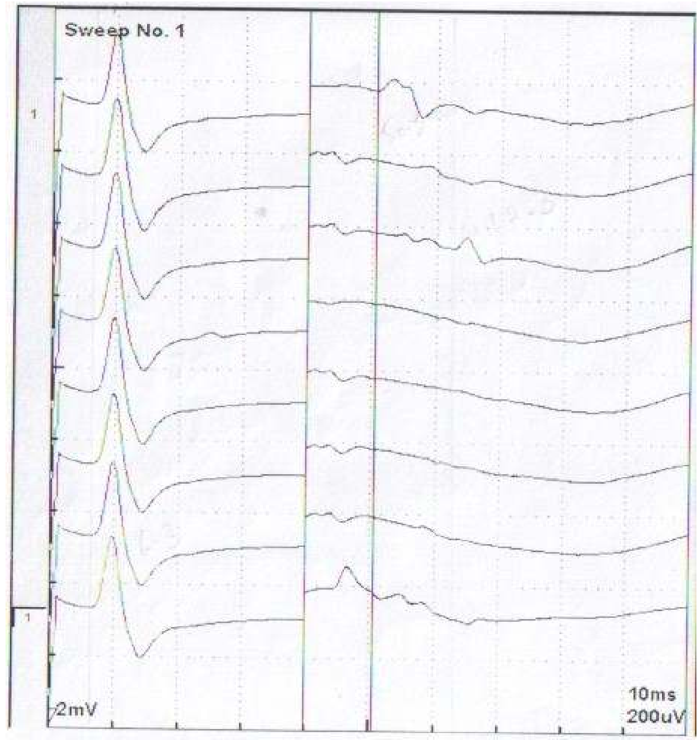

Figure 3. F wave parameters in people with one month post-stroke duration and MAS Grade 1

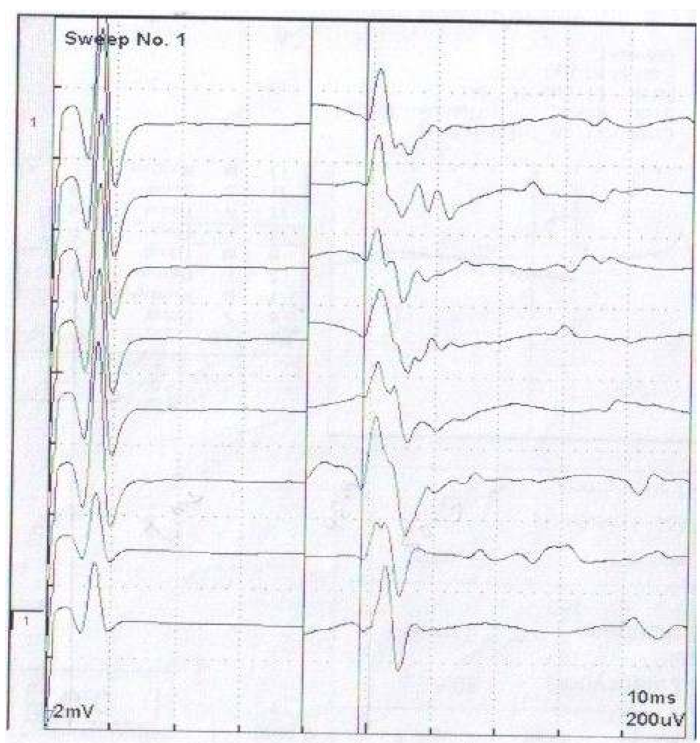

Figure 4. F wave parameters in people with four month post-stroke duration and MAS Grade 2

Latency of F-wave is the most commonly reported parameter which measures the neural conduction of motor axons and the normal value for the Tibial nerve F-wave latency is 46 (6) m/s [16]. In current study, the minimum latency of F-wave for people scoring grade 1, 1+ and 2 spasticity on MAS was 48.47, 45.4 and 44.74 m/s respectively. The latency of F-wave was not correlated to scores of MAS and post stroke duration. Chroni et al. [19] demonstrated that latency of F-wave did not reveal any significant deviations in people early after stroke compared to those of matched controls. Electro neurophysiologists also believe that F-wave latency reflects a combination of the conduction velocity of the peripheral compound action potential and the distance traveled. It is proposed that conduction velocity across lower motor neuron may not be altered by central excitability of alpha motor neurons and it does not reflect alpha motor neuron excitability. Factors like height of an individual, age, limb length [14,18] and latency variance between affected and unaffected sides might attribute for the change of F-wave latency. As these factors were not considered in this study, authors warrant caution in interpreting and analyzing the results. Most of the electro diagnosticians recommend 20 to 40 F-wave responses particularly for research studies. The number of F-wave studied in this study was small which could possibly influences the results. Another limitation of this study is that the height of the participants was not considered since it is believed to be strongly correlated with latency of F-wave. Parameters of F-wave from healthy soleus muscle would provide additional details to interpret the study findings.

We chose soleus muscle instead of distal foot muscles because MAS is usually tested in soleus muscle in routine clinical examination. There is a possibility of F-waves being mixed-up with H-reflex which is typically increased in people with spasticity. Small sample size and the effects of anti-spastic medications at the time of test procedures could also be considered as the potential limitations of this study. Furthermore, the parameters of F-wave like amplitude, F-max/M-max ratio were not compared to MAS scores. Participants were in the early recovery stage with the mean post stroke duration of 2.26±1.18 months. Hence, the severe muscle spasticity as measured on MAS grade ≥ 3 was not present in the study population. Future studies addressing the correlation of MAS grade ≥ 3, the frequently observed tonal impairments in late stage stroke with the parameters of F-wave might provide further insight to assessment of spasticity and clinical utility of modified Ashworth scale.

5. CONCLUSION

A strong correlation was found between scores of MAS and persistence of F-wave in soleus muscle. Also, there were more occurrences of F waves upon stimulation with increased post stroke duration. All the study participants scored less than 2 on MAS indicates that the severe tightness due to non-neural adaptations of tissues may not be common during initial four months duration after stroke. We quote that modified Ashworth scale may be considered as a relevant measure of alpha motor neuron excitability in early stage stroke when the non-neural muscular stiffness is not common. Inclusion of MAS ≥ 3 grade in the future studies might bring new knowledge concerning the alpha motor neuron excitability indicators of F-wave in spastic soleus muscle for people with chronic stroke.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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