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Original Research Article

RELATIONSHIP OF ASSOCIATED REACTIONS IN THE HEMIPLEGIC ARM AND LEG WITH SPASTICITY

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ABSTRACT

Background: Associated reactions may be observed in several neurological conditions involving upper motor neuron disorders and more frequently in hemiplegic extremities. The patient's ability to control associated reactions is generally considered an index of their motor performance. The severity of spasticity and its relationship with the severity of associated reactions have not been explored much. Moreover, as many studies have not been made in the ankle, an attempt has also been made to study the associated reactions in the ankle, based on Brunnstrom's assertion that in the lower limb, associated reactions are of the opposite type to the movement employed to evoke the response.

Purpose of the Study: The purpose of the study is to find the relationship between the severity of associated reactions and the severity of spasticity in the hemiplegic arm and leg, the relationship between the maximal voluntary force exertion and the associated reactions in the hemiplegic arm, and to find out which muscle group is over firing during contra lateral maximal voluntary force exertion in the hemiplegic arm and leg.

Materials and Methods: A descriptive study design has been used in this study, with a sample of 20 hemiplegic subjects with post CVA duration from 1 – 3 years. The sample consisted of both right and left hemiplegics of age between 45 and 65 yrs., including both the ischaemic and haemorrhagic causes of lesion. The study on the relationship of associated reactions with spasticity was made on the 20 hemiplegic subjects in terms of electrical muscle activity and elbow and ankle movement in the paretic arm and leg using surface electromyography and clinical goniometry respectively.

Results: There is considerable variability in the magnitude of associated reactions seen in patients with spasticity. The electrical activity of associated reactions is widespread among the flexors of elbow and wrist and is predominant in the dorsiflexors of ankle. The study also shows that there is considerable variability in the amplitude of associated reactions when correlated with the force exerted on the normal side.

Conclusion: This study has the potential to be useful in the evaluation and treatments aimed at reducing associated reactions and spasticity in the hemiplegic patients.

KEY WORDS: Associated reactions, Spasticity, Hemiplegia, Electromyography, Goniometry.

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INTRODUCTION

Stroke or CVA which is caused by ischaemic or haemorrhagic lesions in the brain, results in impairments of sensory, motor, cognitive, perceptual and language functions. The degree of involvement of these impairments may vary greatly among patients with hemiplegia, yet numerous common characteristics like reflex tensing of muscles and involuntary limb movements are frequently observed.Often intentional movement of one limb is accompanied by unintentional movement of the contra lateral limb [1]. This response has been variously termed 'Associated Movement' [2]; Motor Overflow' [3]; 'Synkinesis' [4]; 'Motor Irradiation' [5]; or 'Associated Reactions' [6]. However, attention has been drawn to the distinction between 'associated movements' and 'associated reactions'. Associated movements refer to normal automatic adjustments of posture when the movements are voluntary. Associated reactions, on the other hand, are abnormal reflex activities that take place in the absence of voluntary movements [6].

Further, associated movements have been divided into purposive and non purposive associated movements, classifying anticipatory postural adjustments simultaneously occurring with the voluntary movement as purposive, and non-purposive associated movements of a pathologic nature, triggered by a voluntary movement, as 'synkinesis' [7,8]. Associated reactions have been defined as automatic activities which fix or alter the posture of a part or parts when some other part of the body is activated voluntarily or by reflex stimulation [9]. Associated reaction may be observed in several neurological conditions involving upper motor neuron disorders and more frequently in hemiplegic extremities, especially during activities that require significant force production [10]. Associated reactions have been reported to be prevalent as a key goal area in 43% of people in a large stroke cohort (n = 964) [11].

There is a controversy over whether to attempt to reduce the synkinetic movement, or to capitalize on the movement in the early stages of recovery in hemiparesis. However, the patient's ability to control associated reactions is generally considered an index of their motor performance.

Associated reactions are seen as pathological movements, indicative of the potential for development of spasticity or the accentuation of the prevailing spastic synergy. However, the severity of spasticity and its relationship with the severity of associated reactions have not been explored much. Hence, the relevance and significance of the present study is beyond question.

Further, it has been asserted that synkinesis on the hemiparetic side generally involves different muscle groups than those utilized during the force generation [8]. Based on this assumption, attempt has been made to study associated reactions in the elbow during the contralateral grip exertion. The elbow joint is frequently the focus of assessment [12], although studies have suggested that associated reactions affect all joints of the upper limb [13, 14].

During rehabilitation of stroke there is often a difference in opinion whether to rehabilitate patients using associated reactions [14] or to prevent them from getting involved in activities that encourage associated reactions [15, 16]. Associated reactions during recovery of stroke are suggested to hinder development of normal movement [17] and therefore rehabilitation is directed at treating these abnormal movements.

Clinicians are often not aware of the impact of associated reactions on their patients, particularly as they may develop some time after the onset of the stroke and are not always related to the presence of spasticity as conventionally defined [18].

Moreover, as many such studies have not been made in the ankle, an attempt has also been made to study the associated reactions in the ankle, based on Brunnstrom's assertion that in the lower limb, associated reactions are of the opposite type to the movement employed to evoke the response.

OBJECTIVES

· To find the relationship between the severity of associated reactions in the hemiplegic arm and leg and the severity of spasticity.

· To find the relationship between the maximal voluntary force exertion and the associated reactions in the hemiplegic arm.

· To find out which muscle group is overfiring during contralateral maximal voluntary force exertion in the hemiplegic arm and leg.

METHODOLOGY

Descriptive study design has been used in this study.

Subject Characteristics: A convenient sample of 20 hemiplegic subjects with post CVA duration from 1 – 3 years was selected for study.

The subjects were taken from various PT clinics and brought to the SRM-PG Lab, Chennai, for the study to be done. Care was taken to obtain written consent from the subjects before they were subjected to the study.

The sample consisted of both right and left hemiplegics of age between 45 and 65 yrs., including both the ischaemic and haemorrhagic causes of lesion.

The selected subjects fulfilled the following criteria:

· Post stroke duration of 1 – 3 yrs.

· Age between 45 and 65 yrs.

· Single CVA.

· Had no receptive aphasia.

· Had good cognitive ability.

· Absence of significant contracture in elbow, ankle.

The subjects were initially evaluated for the spasticity using Modified Ashworth Scale (MAS) in,

· Elbow flexors and extensors

· Wrist flexors and extensors

· Ankle dorsiflexors and plantarflexors

The resting amplitude and maximal voluntary amplitude of Biceps Brachii and Tibialis Anterior as well as the maximal voluntary range of motion at elbow and ankle were also evaluated initially.

Instrumentation and protocol:

For upper limb: Each subject was seated on a high sitting chair with feet resting on a footstool. The upper limb to be evaluated was kept at 15° of shoulder abduction, 10° of shoulder flexion, full extension of elbow and forearm in neutral position. The unaffected upper limb was kept in a position of adducted and neutrally rotated shoulder, elbow flexed at 90°, forearm neutral and wrist between 0-30° dorsiflexion for effective grip exertion.

The efforts demanded from the subjects were three contralateral hand grips. This task was selected to limit associated trunk and limb movements that are related to postural adjustments of body segments during heavy resistive exercises. A Jamar dynamometer was used to measure hand grip force.

Each subject was instructed to reach a maximum handgrip on the unaffected side within ten seconds and to maintain it for one second. Surface EMG being the most commonly used laboratory-based method [12], simultaneous EMG and Goniometric recordings were done on the hemiparetic side. Three such trials separated by one minute rest-period were carried out. The highest readings were taken for the study.

EMG activity of biceps brachii and flexor digitorum and Goniometric measurement of elbow flexion of the hemiparetic upper extremity were recorded during the contralateral grip exertion.

Surface electrodes were placed along the axis of the muscle fibres, on the bulk of the biceps (at the midpoint of the line connecting the anterior axillary line and mid cubital fossa) and on the flexor digitorum by grasping the supinated forearm pointing the index finger to the biceps tendon and placing the electrodes just medial to the tip of the index finger.

A standardised clinical goniometer with its axis on the lateral epicondyle of humerus, and stable arm along the lateral midline of humerus and movable arm along the lateral midline of radius, secured with velcrose straps was used to measure the abnormal elbow flexion in the paretic arm during associated reactions.

For lower limb: The position of the patient was the same as in the study of the associated reactions in the upper limb. Hips were positioned at approximately 80° of flexion; knees were flexed at 90°, and the trunk was secured with straps. The efforts demanded from the subjects were three contralateral plantar flexions on an “Ankle Exercisor”.

The standardised clinical goniometer was used to measure the maximal voluntary plantar flexion while performing on the ankle exerciser. Each subject was instructed to perform a maximal voluntary plantar flexion on the unaffected side in 10 seconds and maintain it for one second. Simultaneous EMG and Goniometric readings on the hemiparetic ankle were taken. Three such trials separated by one minute rest-period were carried out.

EMG activity (amplitude) of medial head of gastrocnemius and tibialis anterior and goniometric measurement of ankle of the affected lower extremity was recorded during the contralateral ankle exertion.

The surface electrodes were placed along the axis of the muscle fibres, on the medial mass of calf, a hand breadth distal to popliteal crease for medial head of gastrocnemius and four finger breadths distal to tibial tuberosity and one finger breadth lateral to tibial crest for tibialis anterior for the measurement of EMG activity.

The standardised clinical goniometer with its axis on the lateral surface of lateral malleoli and stable arm along the lateral midline of fibula and movable arm parallel to lateral aspect of fifth metatarsal, secured with velcrose straps was used to measure abnormal range of motion in the paretic ankle during the associated reactions.

RESULTS AND DISCUSSION

In stroke patients, when voluntary efforts were given on the unaffected side, they were found to elicit involuntary movements at almost all of the joints of the affected limb. While synkinesis has been used in the early stages of motor rehabilitation in hemiplegia on the basis that this may promote motor performance, few studies have described synkinesis from a quantitative perspective. As it has already been reported [19] that the tone of the muscle influences the associated reactions, an attempt was taken to study the relationship between severity of spasticity and associated reactions, and the following observations were made.

According to figure 1, there is a statistically significant change in resting amplitude and maximal voluntary amplitude of Biceps & Tibialis Anterior. This shows that there exists some electrical activity of these muscles at rest due to the sustained moto-neuronal excitability, and this electrical activity is increased during the performance of the voluntary movement due to the motor unit recruitment. Thus, the subjects were able to perform voluntary movement in a synergic pattern as influenced by spasticity. It has already been demonstrated that unilateral elbow flexion caused diffuse motor overflow from proximal to distal muscles on the impaired side (within-limb motor overflow) [20].

Fig. 1: Comparison of resting amplitude and maximal voluntary amplitude of biceps brachii & tibialis anterior.

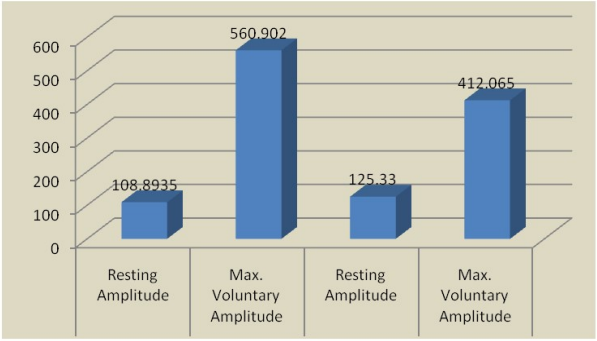


Figure 2 shows the changes in the resting amplitude and amplitude of associated reactions in Biceps Brachii, Flexor Digitorum, Tibialis Anterior and Gastrocnemius which are statistically significant because of the presence of motor irradiation during contralateral efforts. This has been explained that, after the onset of a stroke, supraspinal control is lost, and tasks which require extreme effort result in an increase in the motor irradiation, which in turn trigger the activity of propriospinal interneurons or contra lateral moto-neurons [21], from non-impaired side to the impaired side (between limb motor overflow) in stroke subjects [20].

Fig. 2: Comparison of resting amplitude and amplitude of associated reactions (ar) at elbow, wrist & ankle

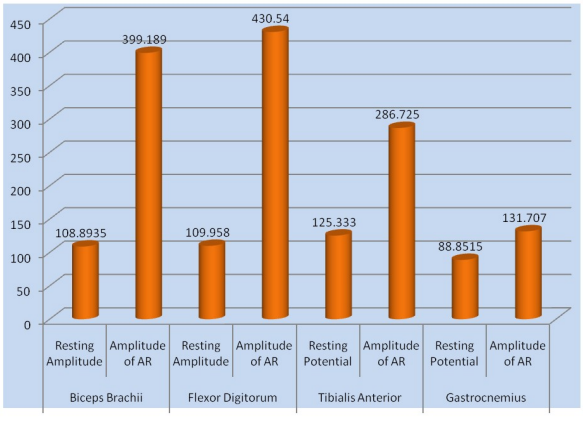


Fig. 3: Comparison of maximal voluntary amplitude and amplitude of associated reactions (AR) of biceps brachii & tibialis anterior.

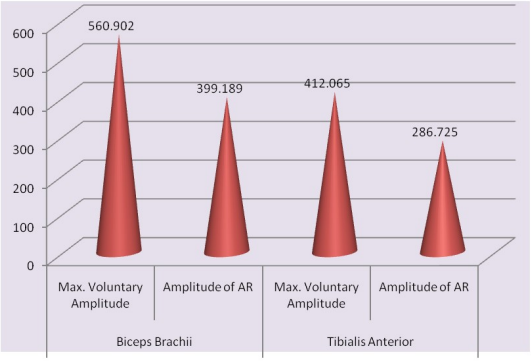
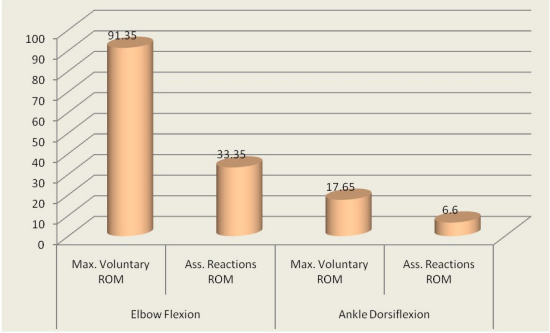
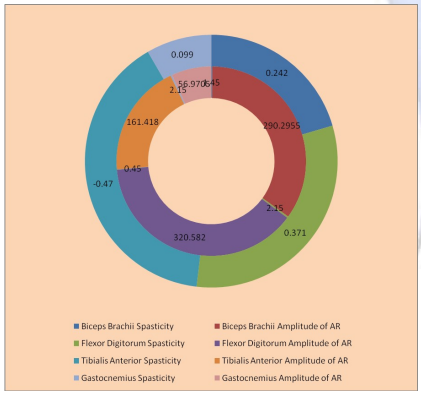


Fig. 4: Comparison of maximal voluntary range of motion and range of motion (ROM) of associated reactions (AR) at elbow & ankle.



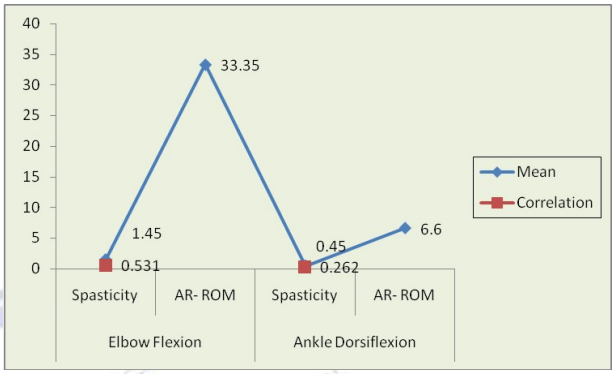
In figures 3 & 4 there are statistically significant changes in maximal voluntary movement and associated reactions. Maximal voluntary movement shows a high value, as the subjects were able to perform significantly in a synergistic pattern. But according to Fulten, associated reactions are only an "automatic modification of the attitude of certain parts of the body when strong volitional movements occur in some other parts". This figure also shows that voluntary control exists to a certain degree in subjects presented with associated reactions. Associated reactions may occur in the affected limb, when the patient has achieved a degree of voluntary control of limb movements [22].

Fig. 5: Correlation of spasticity and amplitude of associated reactions (AR) at elbow, wrist & ankle



The figure 5 shows the relationship of Spasticity and Amplitude of AR in which Biceps Brachii, Flexor Digitorum and Gastrocnemius show a weak positive correlation and Tibialis Anterior shows a weak negative correlation and all are statistically non- significant.

Fig. 6: Correlation between spasticity and range of motion of associated reactions (AR) at elbow & ankle.



The figure 6 shows the correlation between spasticity and ROM of AR which is statistically significant at elbow at the level of 0.05 and a weak positive correlation at ankle which is statistically non- significant.

Figures 5 & 6 show non-significant relationship between spasticity and associated reactions. This has been already proved that, despite central facilitation of abnormal muscle activity with effort, disuse atrophy of paretic target muscles may not generate sufficient force to be measured [23]. It is also claimed that associated reactions may be absent due to inadequate reinforcement, though maximal effort has been used. Associated reactions may develop some time after the onset of the stroke and are not always related to the presence of spasticity [18]. The voluntary strength can influence the magnitude of synkinesis in hemiparetic patients [23].

In figure 6, there is a statistically significant relationship between spasticity and range of motion of associated reactions in elbow. This is in accordance with the statement that there exists a relationship between abnormal elbow movement & magnitude of spasticity [24].

Recent studies have demonstrated involuntary activation of spastic muscles during and after voluntary contraction [25, 26, 27]. When reticulospinal pathways are stimulated by acoustic stimulation during sustained elbow flexion, the induced force increase is similar between

stroke survivors with spasticity as compared to healthy subjects [28]. Motor overflow is often found in stroke survivors with spasticity. Its relation with post-stroke spasticity remains controversial. Motor overflow is found to be associated with spasticity in some studies [29, 24, 30], but not in others [31, 23].

The figure 7 shows a weak positive correlation between Maximum Voluntary Grip Force and Amplitude of AR at Biceps Brachii and Flexor Digitorum which is statistically non- significant.

The figure 8 shows the differences in the amplitude of AR in Biceps Brachii and Flexor Digitorum during contralateral maximal voluntary grip exertion, which is statistically non- significant at 0.05 level.

The figure 9 shows the differences in the Amplitude of AR in Tibialis Anterior and Gastrocnemius, during contralateral maximal voluntary plantarflexion, which is statistically significant at 0.05 level.

Fig. 7: Correlation between maximum voluntary grip force (MVGF) and amplitude of associated reactions (AR) at elbow & wrist.

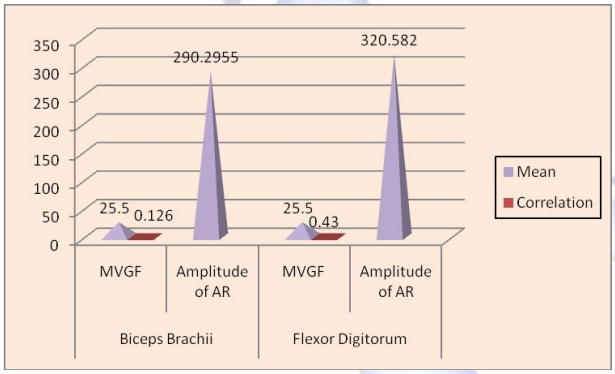


Fig. 8: Comparison of amplitude of associated reactions (ar) of biceps brachii and flexor digitorum.

Figures 7, 8, 9 show the relationship between voluntary force exerted on the contralateral side and the amplitude of associated reactions in the biceps brachii, flexor digitorum, tibialis anterior and gastrocnemius. As per previous studies, predominant movement is wrist flexion during contra lateral grip exertion [18] and in proximal musculature [23]. But it has been observed in this study, that there exists a non-significant relationship between voluntary force exerted and amplitude of associated reactions and also a non-significant difference in the amplitude of associated reactions between biceps brachii and flexor digitorum. This may be due to the widespread EMG activity in contralateral muscles during high levels of force as explained by other studies [23, 8], which stated that global synkinesis on the hemiparetic side generally involves different muscle groups than those utilized during the force generation. Motor overflow to the spastic muscles is non-selective, diffuse, and concomitant with voluntary activation of other muscles and contra lateral muscle contractions produced a widespread GS throughout the affected upper limb [32].

Fig. 9: Comparison of amplitude of associated reactions (ar) of tibialis anterior and gastrocnemius.

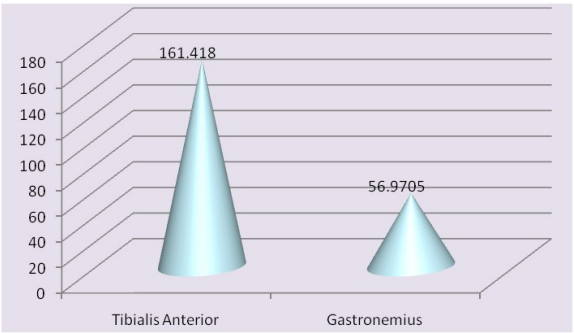


Figure 9 shows statistically significant differences in the amplitude of associated reactions between tibialis anterior and gastrocnemius during contralateral maximal voluntary plantar flexion. The amplitude of associated reactions in tibialis anterior shows a high value. This is in accordance with the observation made that in the lower limb, the reactions were of the opposite type to the movement employed to evoke the responses [22]. This figure also shows the presence of electrical activity during associated reactions in both the opposing groups of muscles. It has been observed that during associated reactions, both the flexor and extensor groups of muscles in the same limb can co-contract [33].

The limitation of this study is the small sample size and further recommendation would be a

study with a large sample size and being more specific with the type of stroke or CVA.

CONCLUSION

In this study, associated reactions were quantified using electromyography & goniometry and were related with different grades of spasticity. It has been found that there is considerable variability in the magnitude of associated reactions seen in patients with spasticity. The electromyographic measures also indicate that, the electrical activity of associated reactions is widespread among the flexors of elbow & wrist and is predominant in the dorsiflexors at ankle. The study also shows that there is considerable variability in the amplitude of associated reactions when correlated with the force exerted on the normal side. This study has the potential to be useful in the evaluation and treatments aimed at reducing associated reactions and spasticity in the hemiplegic patients.

ABBREVIATIONS

CVA - Cerebrovascular accident
MAS - Modified Ashworth Scale
EMG - Electromyography
AR - Associated Reactions
ROM - Range of Motion
GS - Global synkinesis
MVGF - Maximum Voluntary Grip Force

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Conflicts of interest: None

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