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ACTIVATION OF ANKLE FLEXOR AND EXTENSOR MUSCLES DURING STRETCH REFLEX , VOLITIONAL ACTIVITY AND POSTURE IN AMBULATORY SPINAL CORD INJURY PATIENTS

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ABSTRACT

EMG activity of ankle dorsal and plantar flexors was compared during passive movements, volitional contractions and standing in 21 spinal cord injury patients with partial lesions of the upper motor neurone at levels from C2 to L2. The patients, who were all able to maintain standing and to ambulate at least in short distance with support, included 3 females and 18 males with ages from 23 to 59 and were studied in average 65 months after injury. Segmental stretch reflex was assessed by passive dorsal and plantar flexions with patients lying supine. Tibialis anterior responded to stretch in 48% of muscles, while the reflex response was present in 90% of triceps surae muscles. Both muscles were similarly coactivated in 64% during the stretch of antagonists, while at the same time, associated maneuvers were activated in 10% of contralateral tibialis anterior and 32% of contralateral triceps surae muscles, regardless which of the two muscles was stretched on the opposite side. Volitional descending control, also assessed with the patients in supine position, was well preserved both in the tibialis anterior and triceps surae: response in 96%, high activation in 68%. Both muscles were also frequently coactivated during volitional contractions of antagonists: 85% of muscles; where the tibialis anterior showed higher activity. Contralateral associated maneuvers were activated more frequently and stronger than at the passive stretch: tibialis anterior 39%, triceps surae 57%, again regardless which contralateral muscle was volitionally contracted. During standing, all triceps surae and 90% of tibialis anterior muscles were activated, the former displaying more phasic, superimposed phasic/tonic or tonic bursting activity. In all the patients, the activity of both muscles was rather well symmetrical in both legs showing the complete or fair symmetry in 90 % of cases at passive stretch, in 95% at volitional contractions, and in 95% at standing. The results indicated the volitional descending control preserved more in the flexors while on the contrary, the extensor activity was more facilitated during the stretch and standing. Participation of postural mechanisms to the partly preserved volitional reciprocal activity thus most likely enabled standing and gait in these patients.

INTRODUCTION

Upper motor neurone integrates control mechanisms for muscle tone, automatic control of posture, volitional activity, as well as co-ordination within body and extremities during various motor acts (1,2). After a partial lesion of upper motor neurone at the spinal cord, these mechanisms are preserved above and below the lesion, only an interaction among them is impaired, resulting in altered, but not absent neurocontrol of muscular activity in the majority of spinal cord injury patients (3,4). A number of these patients eventually recover their motor functions, including postural ability and even ambulation with or without a support of assistive devices, whereas their altered neurocontrol is reflected in their motor activities.

Ambulatory spinal cord injury (ASCI) patients are suffering from upper motor neurone dysfunctions with neurological findings for altered muscle tone and muscle weakness during nonvolitional as well as volitional activity (5). In this study, ankle flexor and extensor muscle groups were examined respectively for responses to externally induced passive stretch, simulating ankle dorsal and plantar flexion, as well as volitionally induced dorsal and plantar flexion, while patients were lying in a supine position. Activity of these muscles was then recorded while patients were maintaining standing position. The working hypothesis was, that patterns of flexor and extensor muscle activity during the passive stretch, volitional movements and standing differ due to diverse interaction of segmental and suprasegmental influences in neurocontrol of muscular activity. Measurements in the supine position were performed to independently assess segmental reflex and volitional functioning, while those during standing assessed reflex and volitional activity together with postural influences.

MATERIAL

In the study, motor unit responses of the ankle flexor and extensor muscles in 21 spinal cord injury patients were compared. The patients, who were all able to maintain standing and to ambulate at least in short distance with support, included 3 females and 18 males, ranging in age from 23 to 59. They were studied 8 to 299 months after their injury; the average period post-onset was 65 months. There were 13 cervical lesions from C2 to C7, 6 thoracic lesions from T4 to T12 and 2 lumbar lesions at L1 and L2. Both motor and sensory functions were partly preserved in all the patients.

METHODOLOGY

EMG activity of ankle flexor and extensor muscles was recorded in both legs. Motor unit activity was detected by surface EMG electrodes taped 3 cm apart over the muscle bellies. Beckman sintered Ag-AgCl or Quinton Quik-Prep pre-gelled, Ag-AgCl loaded, disposable electrodes were applied. Stripchart ink jet recorder Elema Schoenander Mingograf EEG16 was used for the recording with bandwidth 3 to 700 hertz and sensitivity 100 microvolts per centimeter.

The activity of tibialis anterior and triceps surae muscles was compared during externally induced passive stretch of both muscle groups and during their volitionally induced contractions, both in the supine position, as well as during standing. Measurements in the supine position were used to independently assess stretch reflex activation and volitional activation without postural influences. At the same time, coactivation of ipsilateral antagonists and accompanying associated maneuvers in contralateral antagonistic pairs of muscles were measured. During standing, an interaction of reflex, volitional and postural mechanisms was recorded (6).

During the passive stretches of triceps surae and tibialis anterior, the patient was asked to relax while his foot was slowly moved first into dorsal then into plantar flexion. With the maneuvers covering full range of motion, the relaxation and the reflex responses were monitored on a stripchart. To carry out the volitional contractions, the patient was asked to flex, hold, relax, extend, hold and relax his ankle. All maneuvers were repeated 3 times on the right, then 3 times on the left leg, and recorded along with event marks denoting their onset. During quiet standing, the activity of tibialis anterior and triceps surae muscles was recorded bilaterally at the same time.

The EMG activity was analyzed with respect to single motor unit potentials, phasic and/or tonic activity, and amplitude. Responses were scored as 0 - no activity, 1 - low activity, 2 - moderate, and 3 - high activity. During standing, combinations of phasic, phasic/tonic, bursting tonic, and continuous tonic activity were distinguished together with the scores of amplitude. Besides the ipsilateral and contralateral activity, symmetry in activation of both legs was also compared during the passive and active maneuvers, as well as during standing. It was defined both in the tibialis anterior and in the triceps surae as a difference between bilateral scores: symmetry = 3 - abs(right score - left score); 3 meaning complete symmetry, 2 - fair symmetry, 1 - poor symmetry, and 0 - no symmetry.

RESULTS

Activity during the passive stretches, volitional contractions and standing is presented for the tibialis anterior and triceps surae muscles by graphs of intensity and nature of activation. Numbers of the muscles in 21 patients are given at no activity (0), low (1), moderate (2), and high activity (3), marked on horizontal axes of the plots. During the stretches and contractions, tonic or no activity is marked by empty bars and superimposed phasic/tonic activity or single motor unit potentials at 0 activity by dotted bars. During standing, absent activity (black bar), phasic (crossed bar), phasic/tonic (dotted bars), bursting tonic (striped bars), and sustained tonic activity (empty bars) are given with correspondent intensities.

Passive Stretch

Direct response of the tibialis anterior and triceps surae to the passive stretch and a simultaneous coactivation of these muscles during the stretch of their antagonists are given in fig. 1. With the patients in the supine position, the tibialis anterior responded to the stretch in 48% of muscles with tonic activation of various intensities. Segmental stretch reflex was more frequent in the triceps surae, where 90% of muscles responded with various phasic/tonic patterns of clonogenic activity. Both muscles were similarly coactivated with mostly low tonic patterns during the stretch of antagonist: tibialis anterior in 64%, triceps surae in 63% of the muscles.

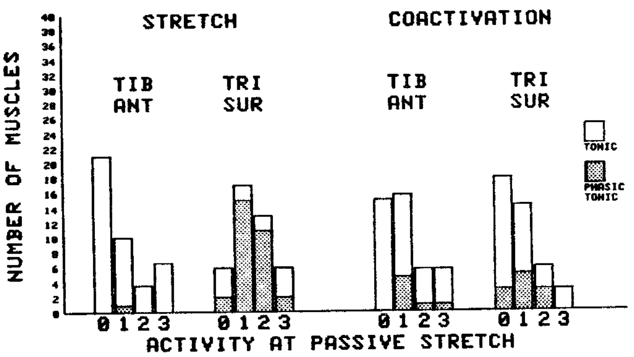

Fig. 1: Size and pattern of stretch reflex response and antagonistic coactivation in ankle muscles of 21 ASCI patients during externally induced passive ankle movements.

Activation of associated maneuvers during the passive stretch of contralateral ankle muscles is given in fig. 2. Low, mostly phasic activity appeared in only 10% of tibialis anterior and in 32% of triceps surae muscles, regardless of which of the contralateral muscles was stretched.

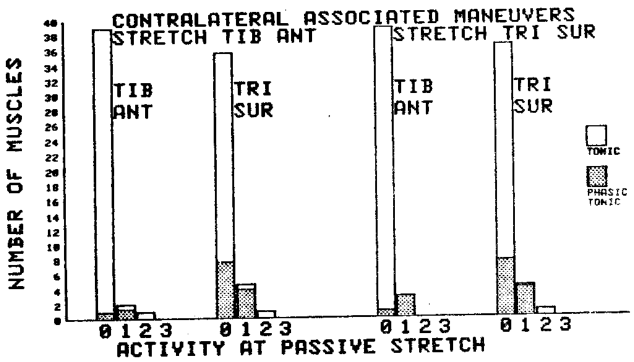

Fig. 2: Size and pattern of associated activation of ankle muscles in 21 ASCI patients during externally induced passive movements of contralateral ankle.

Volitional Contractions

Volitional activation of the tibialis anterior and triceps surae muscles and simultaneous coactivation of their antagonists with the patients in the supine position are given in fig. 3. Volitional control was well preserved in both muscles: altogether 95% of tibialis anterior and 98% of triceps surae muscles were activated, while 74% of tibialis anterior and 62% of triceps surae showed high tonic volitional activity. Both muscles were more frequently coactivated during the volitional contractions of their antagonists than during the passive stretch. The coactivation took place in 83% of tibialis anterior with moderate or high tonic activity, while 87% of triceps surae showed low or moderate tonic and phasic/tonic coactivation.

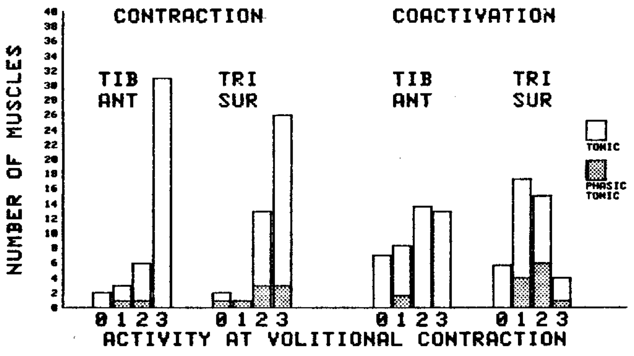

Fig. 3: Size and pattern of activation and antagonistic coactivation in ankle muscles of 21 ASCI patients during volitional movements.

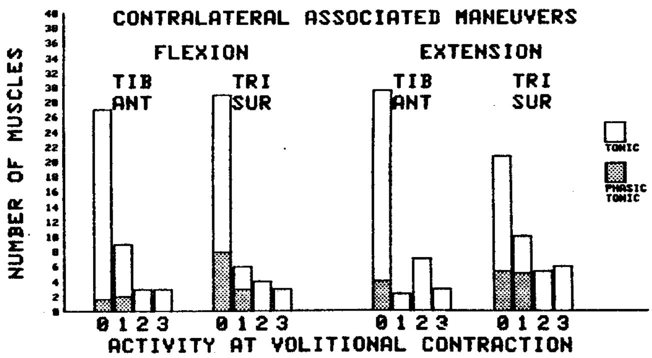

Fig. 4: Size and pattern of associated activation of ankle muscles in 21 ASCI patients during volitional movements of contralateral ankle.

Activation of associated maneuvers during the volitional contractions on the opposite ankle muscles is given in fig. 4. The contralateral associated maneuvers were more frequent and stronger than during the stretch reflex responses: 39% of tibialis anterior muscles showed mostly tonic activity with various intensities both during the contralateral volitional ankle flexion and extension, while 50% of triceps surae muscles were activated during the contralateral volitional flexion and 63% during the extension, again mostly tonically with various intensities.

Standing

Activation of the tibialis anterior and triceps surae muscles during standing is given in fig. 5.

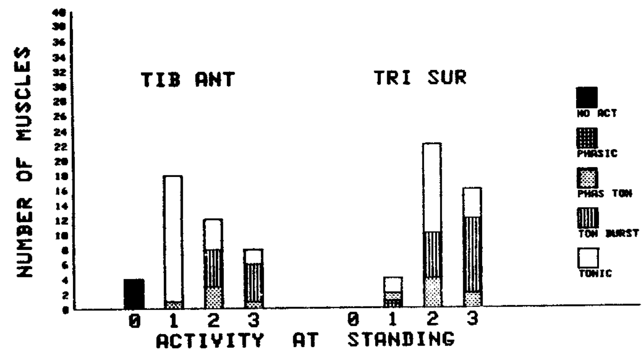

Fig. 5: Size and pattern of activation of ankle muscles in 21 ASCI patients during relaxed standing.

During the relaxed standing position, all the triceps surae muscles and 90% of tibialis anterior muscles were active. The amplitude of tibialis anterior response was mostly low and moderate with the phasic/ tonic, bursting tonic, and tonic activations. At the same time, the triceps surae displayed mostly moderate and high activity with the phasic, phasic/tonic, bursting tonic, and sustained tonic patterns.

Symmetry

Symmetry in the activation of tibialis anterior (empty bars) and triceps surae muscles (dotted bars) in both legs of the 21 ASCI patients is presented in fig. 6. The symmetry was defined as a reverse difference of the bilateral scores of activity: 3 minus absolute difference between right and left score. As it can be seen in fig. 6, both the activity of flexor and extensor muscles was rather well symmetrical when compared bilaterally in all the patients.

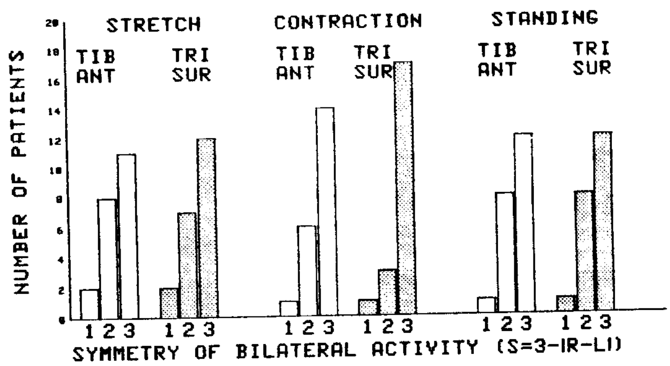

Fig. 6: Symmetry of bilateral activation of ankle muscles in 21 ASCI patients during passive stretch, volitional contraction and standing.

Complete - 3 or fair symmetry - 2 were found at both muscles in 90 % of the ASCI patients during the passive stretch and in 95% respectively during the volitional contractions and standing. The complete symmetry was higher in the extensors during the passive stretch: tibialis anterior 52%, triceps surae 57%, and volitional contractions: tibialis anterior 67%, triceps surae 81%, while during standing, both the flexors and extensors acted completely symmetrically in 57% of the cases.

DISCUSSION

Patients with partial lesions of upper motor neurone at the spinal cord were studied to compare segmental reflex mechanisms, long loop postural mechanisms and volitional descending mechanisms in the neural control of distal leg muscles. With the intact mechanisms themselves, only their functional integration is impaired below the level of spinal cord lesion in these patients.

The independent assessment of segmental stretch reflex responses pointed out a released hypertonic activity, which was more facilitated in the extensors. At the same time, frequent coactivation of antagonists indicated an impaired reciprocal inhibition. Rather well preserved central volitional control of muscle activation facilitated the activity of flexors, while the reciprocal inhibition was further suppressed, displaying higher coactivation of both the flexors and extensors. So, the execution of intended movements was disturbed. Irradiation of activity to the contralateral muscles, which was low during the segmental reflex responses, also considerably increased during the volitional control, further preventing the intended motility.

During standing, postural descending control was added to the patterns of segmental reflex and volitional activity. Similar to the segmental stretch reflex responses, the long loop postural mechanisms facilitated the extensor activity. Therefore, it can be assumed, that the postural control, which contributed suppressing the described severe disturbances in the reflex and volitional control, most likely enabled the standing and restricted gait in 21 studied ASCI patients.

The described results and their interpretation indicate two distinct possible approaches in the restoration of impaired postural and locomotor abilities by external control. The present, widely used kinesiological approach is trying to substitute the diminished or absent volitional control, where and when the muscular contractions are required. The outcome of this approach is frequently restricted by the unwanted accompanying motor responses, while posture is mostly provided by passive assistive devices. The discussed results are suggesting another, not yet explored possibility: an augmentation of the indispensable postural control and its integration with the volitional and reflex mechanisms.

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