

SHORT REPORT

Activation of selected trunk muscles during symmetric functional activities in poststroke hemiparetic and hemiplegic patients

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Abstract

Objective—To compare the EMG activity between the recti abdominii muscles and between the lumbar erector spinae muscles in hemiparetic and hemiplegic patients during functional symmetric trunk movements and to compare patients' EMG activity profiles with those of healthy controls.

Methods—EMG activity from the selected muscles was recorded during three symmetric and time controlled trunk exercises. Data analysis was based on values of cross correlations and of ratios between EMG activity of the bilateral corresponding muscles.

Results—In all groups, the highest cross correlations were obtained for both muscles when the muscles acted as prime movers. For the recti abdominii muscles, these values in the patients were comparable with those of the healthy subjects, whereas for the extensor muscles, the highest synchronous activity was displayed in healthy subjects and the lowest in hemiplegic patients. Laterality differences in the amount of EMG activity of the recti abdominii muscles were not biased towards one side. For the extensor muscles, in the controls, the activation levels were higher in the left erector spinae muscle than in the right one in two of the three exercises. Similarly, in the extensor muscles of the hemiparetic patients, activity on the paretic side was higher than on the non-paretic side in two exercises.

Conclusions—In patients with a supratentorial poststroke hemiparesis or hemiplegia, bilateral corresponding axial trunk muscles co-contract during symmetric trunk activities. Synchronous activation is at its highest level during voluntary dynamic tasks and is greater in the recti abdominii than in the erector spinae muscles. For both muscles, EMG activation levels on the paretic side were not lower than on the non-paretic side. Thus, the assertion that the muscles on the paretic side are activated to a lesser extent than their counterparts on the non-paretic side

during symmetric trunk movements was not confirmed.

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Keywords: stroke; hemiparesis; hemiplegia; rehabilitation; trunk

Hemiparesis caused by upper motor lesions is known to be more detrimental to distal than to proximal body musculature.^{1,2} This "proximal to distal" gradient of impairment is explained by the fact that motor neurons innervating axial and proximal limb muscles receive both ipsilateral and contralateral descending inputs, whereas peripheral muscles are supplied by motor neurons, of which the supraspinal input is mainly contralateral.³⁻⁵ Hence, the rationale for the current emphasis placed by physical rehabilitation disciplines on restoration of the function of trunk and girdle muscles^{6,7} is perplexing. Furthermore, objective evidence of contralateral (opposite the lesion side) mal-function of axial and proximal muscles in post-stroke hemiparetic patients is sparse, and what there is relates mainly to their role in postural adjustments⁸ and not as prime movers. In the current work we questioned the assertion that axial muscles on the paretic side are less activated than their counterparts on the non-paretic side. We studied the function of the rectus abdominis and lumbar erector spinae muscles of hemiparetic and hemiplegic patients during basic symmetric functions of daily life.

Methods

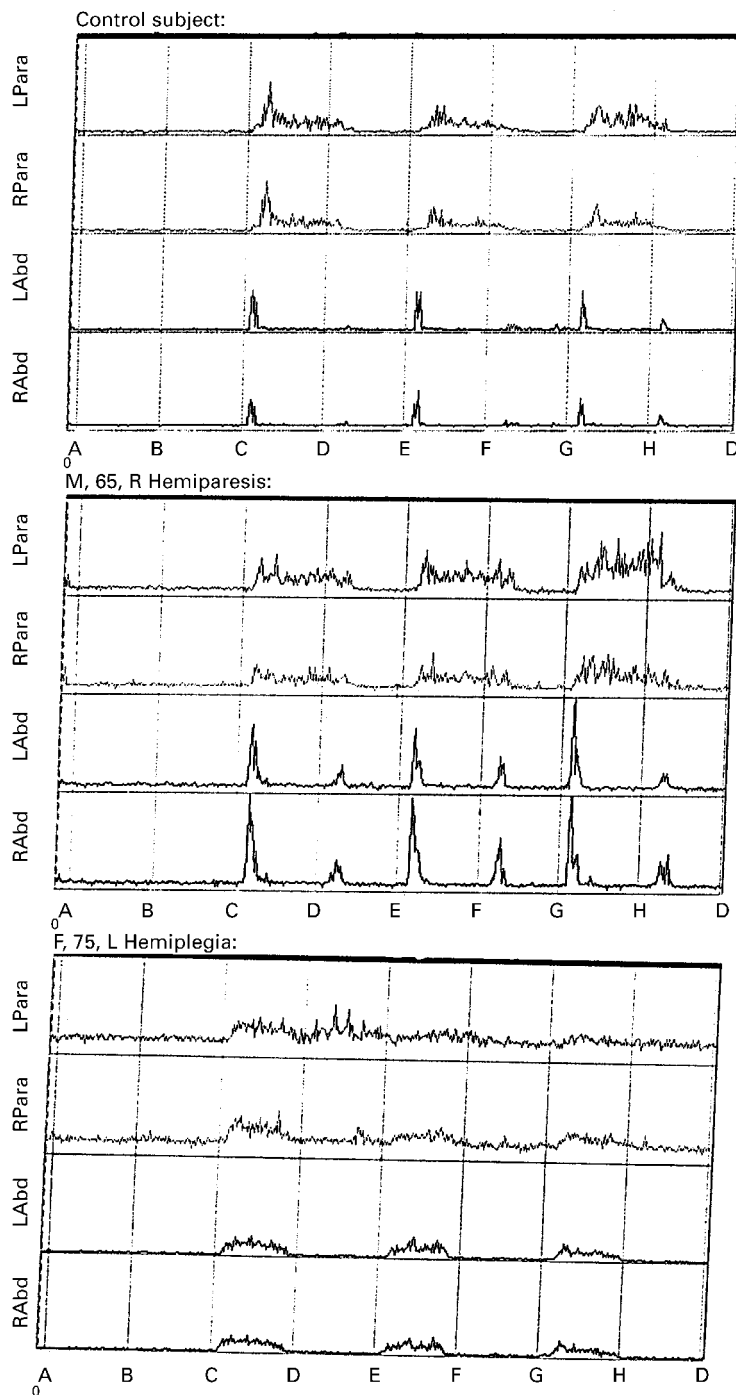
SUBJECTS

The study involved 41 patients who were residents of a rehabilitation hospital and who had a single unilateral thromboembolic stroke in the territory of the anterior brain circulation and 20 healthy controls (eight men, mean age 69 (SD 7.5) years). The assignment of patients to either the "hemiparetic" or "hemiplegic" group was based on the severity of the paralysis as reflected by the ability to stand up without or with assistance respectively. There were 10 and 12 patients with left side paralysis and 11 and eight patients with right side paralysis (mean age 72.7 (SD 9) and 75.6 (SD 6.9) years) in the hemiparetic and hemiplegic group respectively. The hemiplegic patients scored substantially

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EMG activity profile of the left and right rectus abdominis (Labd and Rabd) and left and right lumbar erector spinae (Lpara and Rpara) muscles during trunk movements to an upright position from reclined sitting (exercise 1, three repetitions). Data shown are from one subject in each group. The time interval between each pair of vertical lines is 6 seconds. The interval between markers A and C designates the baseline period which is followed by the three repetitions of the exercise.

Mean values of cross correlation between left and right (paretic and non-paretic) lumbar erector spinae and between the left and right (paretic and non-paretic) rectus abdominis muscles in healthy controls and in hemiparetic and hemiplegic patients. Bringing trunk forward, extending back, standing up

	Erec sp	Rect ab	Erec sp	Rect ab	Erec sp	Rect ab
Controls	0.71	0.84	0.69	0.54	0.82	0.63
Hemiplegic	0.49	0.82	0.43	0.52		
Hemiparetic	0.65	0.81	0.73	0.55	0.73	0.58
ANOVA	$F=8.74, p=0.0005$	NS	$F=22.4, p=0.0000$	NS	$F=6.7, p=0.01$	
Post hoc	*		*		*	

NS=Non-significant. *For exercises 1 and 2 implies a significant lower cross correlation value between the erector spinae (Erec sp) muscles in the hemiplegic patient group compared with the equivalent values in the other groups. For exercise 3, the hemiparetic patients had significantly lower values than the controls. Rect ab=recti abdominii.

lower than the hemiparetic patients on the Barthel index scale,⁹ the Brunnstrum scale,¹⁰ the trunk control test,¹¹ and the functional reach test (performed while seated).¹²

INSTRUMENTATION AND PROTOCOL

The subjects were tested while seated on a chair (46 cm height) with side and vertical rests. Testing was initiated after skin preparation and attachment of EMG electrodes, and consisted of the following three exercises, each of which was performed three times.

(1) From reclined sitting (120° hip flexion) and hands on contralateral shoulders, bringing the trunk forward beyond 90° of hip flexion; (2) from upright sitting (90° hip flexion) in a relaxed posture, shrugging shoulders backwards and extending the back; (3) from reclined sitting (120° hip flexion) and hands clasped forward to standing up (the hemiplegic patients were unable to stand up unassisted and did not perform this exercise).

Electromyography data (0–500 Hz bandwidth, 1000 Hz sampling frequency) were collected during a baseline period of 12 seconds as well as during the performance of three 6 second long repetitions of each exercise. Inter-repetition intervals were also 6 seconds long. The data were rectified and integrated over periods of 10 ms and stored for later analysis.

DATA ANALYSIS

Cross correlation was used to calculate the level of temporal synchronisation between the activity profile of corresponding bilateral muscles using a standard formula.¹³

The ratios between mean EMG activity of the same muscle on each side (left/right (L/R) in the controls and paretic/non-paretic (P/NP) in the patients) were also calculated and tested against the null hypothesis so that this ratio equals 1.

One way analysis of variance (ANOVA) followed by post hoc Bonferroni pairwise comparisons of means was used for group comparisons. Student's *t* tests were applied to compare the amount of activity between corresponding bilateral muscles.

Results

Examples of data recorded during the first exercise from one healthy subject, one hemiparetic patient, and one hemiplegic patient are depicted in the figure.

TIMING OF MUSCULAR ACTIVATION

Cross correlation values (table) between the two recti abdominii muscles were highest in

exercise, which involved concentric bilateral contraction. Between group differences, however, were not found in any of the three exercises. In the erector spinae evaluation, cross correlation between the two sides was significantly lower in the hemiplegic group compared with both the controls and the hemiparetic subjects in both exercise 1 and 2. In exercise 3, cross correlation between the erector spinae of the two sides was significantly lower in the hemiparetic patients compared with the controls.

AMOUNT OF MUSCULAR ACTIVATION

For the controls, differences between the left and right erector spinae muscles were found in both exercise 1 and 3, with the left muscles being significantly more active than the right ones ($t=2.13$, $p=0.03$ and $t=4$, $p=0.0007$, respectively). No laterality differences were encountered for the rectus abdominis muscle in any of the three exercises. In the hemiparetic patients, the erector spinae muscles on the paretic side yielded a significantly higher activity level than those on the non-paretic side in exercises 2 and 3 ($t=2.18$, $p=0.04$ and $t=2.05$, $p=0.05$, respectively), whereas the rectus abdominis on the paretic side was less active in exercise 2 ($t=2.31$, $p=0.03$). In the hemiplegic group of patients, no laterality bias was found in both exercises and for both muscles.

Discussion

Synchronisation between EMG records of bilateral axial muscles is implied by high positive correlation values between the corresponding muscles and could indicate a common drive simultaneously subserving bilateral motor neuron pools.⁴ For the recti abdominii muscles, this degree of synchronisation was comparable in our three study groups, being the highest when the muscle served as a prime mover (exercise 1) and lower during stabilisation and restraint actions. These results are consistent with the findings of Carr *et al* for healthy subjects,⁵ and we further extended them to apply to poststroke patients. For the erector spinae muscles (exercises 2 and 3), the correlations between the two sides in the hemiplegic patients were significantly lower than in the healthy and hemiparetic subjects, indicating that for severely afflicted patients, simultaneous activity of both sides might be impaired both when the muscles serve as prime movers (exercise 2) or for restraint (exercise 1). Alternatively, comparable values of cross correlation were obtained for the healthy subjects and the hemiparetic patients, indicating that normal coactivation of corresponding bilateral muscles can prevail with slight paralysis. During the standing up action (exercise 3, the hemiplegic patients exempted), synchronous activity of the erector spinae muscles was the highest, pointing again to the association between high correlations and the role of the muscle as a prime mover. This correlation was higher in the healthy subjects than in the hemiparetic patients, implying that coactivation of the lumbar erector spinae muscles in hemiparetic patients could have deteriorated somewhat.

No laterality bias was found in any group in the amount of EMG activity of the recti abdominii muscles in the exercises which involved dynamic shortening of these muscles (exercises 1 and 3). The higher activation levels on the non-paretic side in the hemiparetic patients in exercise 2 do not seem to convey important information because the prime movers for performing this exercise are the erector spinae muscles, whereas the abdominal muscles display mainly low level tonic activity. In view of the comparability in the bilateral function of these muscles in both groups of patients and healthy controls, the claim of an existing malfunction of the abdominal muscles in poststroke patients⁶ was not confirmed. Moreover, the fact that the recti abdominii muscles displayed a normal coactivation pattern in the two patient groups provided compelling evidence of their intactness during performance of symmetric voluntary motor tasks. As for the erector spinae muscles, laterality differences in the magnitude of EMG activity were found both in the healthy subjects and in the hemiparetic patients in two of the three exercises: in the control group, the muscle on the left side had higher activity levels than the corresponding right one, whereas in the hemiparetic patients, the muscle on the paretic side showed higher activity levels than the corresponding muscle on the non-paretic side. A likely explanation for these findings might be related to the higher recruitment rate of motor neurons as an a priori compensation for real or perceived weakness.¹⁴ Such weakness, if it exists, would probably have been more apparent with more strenuous or longer lasting exercises. Noteworthy of mention here is the report by Gandevia and McCloskey, who found that hemiparetic patients consistently overestimate the magnitude of forces generated on the paretic side.¹⁵

Impairment of trunk control in hemiplegic or paretic patients has often been documented and characterised by asymmetry in performance of rotatory and side bending activities.^{11 16 17} Trunk control has been shown to be a valid predictor of stroke rehabilitation outcome and to correlate positively with established functional and motor assessments.¹¹ Nevertheless, the link between deficiencies in performance of trunk movements and malfunction of either individual or groups of trunk muscles has not been established. The findings of the current study pointed to normal function of the abdominal axial muscles in symmetric activities, whereas the results for the lumbar extensor muscles were less conclusive. Further clarification of the role of trunk muscles and of the nature of their impairment in poststroke patients is required in a broad repertoire of activities. The knowledge to be gained is imperative for planning rational rehabilitation strategies.

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