EFFECTS OF UPPER AND LOWER LIMB STATIC EXERTIONS ON GLOBAL SYNKINESES IN STROKE PATIENTS

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ABSTRACT

Global synkineses are stereotyped involuntary muscle activities or movements that occur on the paretic limbs of stroke subjects during voluntary movements or efforts realized on the paretic or non paretic side. Involuntary muscle activities on the affected upper limb of 11 hemiparetic subjects (HS) and on the left or right upper limb of 10 control subjects (CS) were recorded using surface electromyography during successive maximal ankle exertions and during contralateral grips. Significant differences in the level of involuntary EMG activities were observed between experimental conditions (ANOVAS, p<0.05). EMG levels in HS were significantly higher during contralateral grip tasks than during the ankle exertions. These results suggest that upper limb global synkineses are more marked in specific tasks and that this task specificity may reflect the neurophysiological mechanisms involved in the generation of GS.

KEYWORDS: Associated movements, overflow, irradiation
INTRODUCTION

Global synkineses are non-purposive pathological involuntary muscle activities or movements elicited in the hemiparetic limbs during voluntary forceful resisted contractions (20, 34, 48). Voluntary efforts in the affected or unaffected extremities of some hemiparetic patients can elicit global synkineses at several or all of the joints of the affected limb or limbs (Figure 1). Their occurrence is common in HS (39) and they often hinder the execution and coordination of purposeful movement.

While the hemiparetic patients’ ability to control global synkineses is generally considered an index of their motor performance (26), controversy remains regarding treatment approaches. There is no consensus on whether to attempt to reduce the synkinetic movement (2, 12, 32) or to capitalize on the movement in the early stages of recovery (10, 46). Although global synkineses have been described extensively in the clinical literature and are well recognized by clinicians, few studies have looked at global synkineses from a quantitative perspective.

The description of global synkineses in the literature has relied mostly on either clinical observations or frequency measurements (1, 2, 8-10, 34, 39, 45, 47, 48). No study has yet documented the influence of either the location or the direction of effort on the pattern and amplitude of global synkineses. Knowledge of the characteristics of global synkineses under different conditions of effort may
provide important information for clinical treatment regardless whether these approaches promote or discourage the harnessing of global synkineses.

Previous studies using multidirectional bi-articular static dynamometry and electromyography (EMG) have shown that upper limb global synkineses during hand grip efforts are graded with the severity of both the paresis and spasticity in HS (7) and they occur in fairly consistent stereotyped patterns or configurations at high level of force. In chronic HS they are highly stable within a session and are more predominant at the elbow than in other joints (4, 5). The purpose of the present study was to assess the effect of different ankle and grip static ramp contractions on the amplitude of global synkineses. A portion of these results has been presented in abstract form (6)
METHOD

Subjects

This project was approved by the ethics committee at the Montreal Rehabilitation Institute and each subject gave informed consent prior to the experiment. Eleven hemiparetics (8 men, 3 women) [HS] and ten control subjects (8 men, 2 women) [CS] participated in this study. The mean ages and standard deviations for the HS and the CS were 42.8 ± 11.4 and 44.2 ± 12.1 respectively. Both groups were comparable in term of gender ($x^2 = 0.15$, $p = 0.70$) and age ($t$-test=$-0.268$, $p= 0.79$).

Before the testing procedure, the global motor performance of each hemiparetic subject was evaluated using the Fugl-Meyer scale (26). The modified Ashworth scale (3) was used to assess muscle tone in elbow flexors and extensors. A summary of the clinical profile of the HS appears in Table 1. Time post-stroke for HS ranged from 2 months to 80 months. Motor performance on the Fugl-Meyer scale ranged from 34 to 97 out of a possible 98 with a mean and standard deviation of 70.4 ± 19.7.

____________INSERT TABLE 1 AROUND HERE____________
Instrumentation and protocol

Each subject was seated in an adjustable chair with his or her trunk secured with straps. Hips were positioned at approximately 80° of flexion and knees were flexed at 90°. The upper limb to be evaluated (EL) was placed into fixation rings rigidly mounted to a reinforced sliding structure attached to the chair. For the control subjects, the right and left upper limb were alternatively positioned in the fixation system. The EL position was constant with the elbow flexed at 90°, the shoulder in slight abduction (15°) and the forearm in neutral position.

The subjects were asked to perform five different maximal grip and ankle tasks. These included contralateral (with respect to the evaluated limb) hand grips, contralateral ankle dorsi-flexions and plantar flexions, and ipsilateral ankle dorsi-flexions and plantar flexions. Grip forces were recorded with a modified prehension dynamometer instrumented with a universal strain gauge tension adaptor. Ankle forces were measured using a bi-directional strain gauge force transducer soldered into the foot platform. Both transducers' outputs were computer interfaced.

Maximal voluntary contraction (MVC) force targets for all tasks were determined prior to the ramp exertions. For each task, MVCs were established with the mean value of three maximal exertions at two-minute intervals executed without feedback. This mean was considered to be the MVC target and was used to plot a ramp template. The force signal recorded from one of the force transducers (prehension or ankle) was displayed alternatively on a computer.
monitor placed in front of the subject. Each subject was instructed to follow a 5 second force ramp reaching the MVC target and maintaining it for one second. Three such force ramps separated by one minute rest periods were executed with verbal encouragement. A one-minute rest period was given between each exertion. The order of the tasks was counter-balanced across subjects using a latin-square design.

Global synkineses were defined operationally as the EMG activity of 4 upper limb muscles on the evaluated limb during maximal contralateral grip and bilateral ankle tasks. For each task, EMG activity was recorded up to the maximal force generated during a 5-second contraction ranging in force from zero to the maximal. EMG activity of the biceps brachii (BB), brachioradialis (BR), triceps brachii (TB) and flexor digitorum (FD) was recorded during the tasks with active surface electrodes placed along the axis of the muscle fibers. Signals were pre-amplified (CMRR = 120 dB, gain = 2000 and band passed at 10Hz to 500Hz) and digitized on line at a frequency of 1000 Hz using an acquisition card.
Analysis

In order to normalize the EMG data, subjects were asked, prior to the execution of the experimental tasks, to exert 3 progressive maximal voluntary contractions (MVC) in flexion-extension of the elbow and 3 maximal grips on the EL. In this manner, the maximal FD activity was measured during grip exertions, while maximal BR, BB and TB activities were measured during flexion and extension of the elbow. The EMG signals were filtered and rectified. Baseline EMG (i.e. activity recorded in the first 200 ms prior to exertion) of each muscle was removed from the EMG values recorded during the ramp contractions. Mean EMG values during a 100 ms window, placed 50 ms before and after the highest force value generated during each task, were computed and averaged for three trials. The mean normalized EMGs for each condition were computed and used to characterized EMG associated with the appearance of global synkineses.

The statistical tests performed on each dependent measure (4 muscle EMGs) included a 2 X 5 ANOVA for repeated measures, with Group (Hemiparetic vs Control) as the between factor and Task (grip, non paretic ankle dorsi flexion, non paretic ankle plantar flexion, paretic ankle dorsi flexion, paretic ankle plantar flexion) as the within factor. Alpha values were fixed at 0.05. Post hoc ANOVAS were performed on each task and each group with the critical p value adjusted for multiple comparisons.
RESULTS

Mean normalized EMGs for muscle activity recorded during grip and ankle exertions are illustrated in Figure 2. For a given muscle, each radial axis corresponds to the EMG recorded during a specific task. NAH represents the contralateral (non-affected) hand grip, NAADF is the contralateral ankle in dorsi-flexion, NAAPF is the contralateral ankle in plantar-flexion, AADF is the ipsilateral (affected) ankle in dorsi-flexion and AAFP the ipsilateral ankle in plantar-flexion. The amplitude of the EMGs is indicated on the length of the axis end. CS values are represented by the black filled lines. HS values are represented by the oversized lines. The outer limit of each graph corresponds to 60 % of the maximal EMG recorded for that muscle.

In CS upper limb EMGs, expressed as a percentage of the maximal EMG, were similar across tasks and ranged from 5 % to 10 % of the maximal voluntary EMG. The most prevalent EMG activity recorded was in the FD muscle during the contralateral hand grips. In contrast, mean EMGs in HS were higher and ranged from 13 % to 28 % during the ankle tasks and from 29 % to 59 % during the hand grip tasks. The greatest EMG activity recorded in HS was in the FD and BB muscles (59 %) during the contralateral hand grips.
Anova results showed significant interactions (p<0.05) between the factor group (HS, CS) and task (NAH, NAADF, NAAPF, AADF, AAPF) for all 4 muscle EMGs recorded (Table 2). This indicates that task effects on the EMG activity are not consistent across the groups. In order to locate these interactions, separate analyses were conducted by fixing the task factor and the group factor. EMG values were compared between each task for each group and between groups for each task. The critical p value was adjusted to account for the number of comparisons. (p=0.05/10= 0.005, p=0.05/5= 0.01) The results of these analyses appear to the right of Table 2.

Mean comparisons of the EMG activity recorded in each muscle between the different tasks for each group showed significant differences between tasks only in the HS group (p<0.005). No significant differences in EMG activity were observed across tasks in the CS group for all four muscles (p>0.005). Contrast analysis using paired t-tests with the Bonferonni correction indicates that for the BB, TB and FD muscles, the amplitude of EMG recorded in HS was higher during the NAH task than during the ankle tasks (p<0.005). Mean comparisons of EMG activity between groups for each task (Table 2B), showed significant differences (P<0.01) in EMG activity of the FD muscle during the NAH task and in the EMG activity of the TB muscle during both NAADF and AAPF tasks. While mean EMG activity recorded in BB, TB, and BR muscles was higher in HS than in CS during the NAH task, this trend did not reach statistical significance required by the adjusted p value (p=0.01).
DISCUSSION

Involuntary muscle activation was quantified in HS and CS using surface electromyography during various high intensity contralateral grip and ankle exertions. In contrast to the low EMG levels recorded in CS, significant EMG activities in BB, BR, TB, and FD muscles on the affected upper limb of HS were observed. However, the level of upper limb EMG activity in HS varied according to the tasks executed by the subjects. The level of EMG activity in the BB, TB and FD muscles observed in HS was higher during the contralateral hand grip tasks than during the ankle tasks. These observations provide evidence that the task executed by the subject influences the manifestation of upper limb global synkineses in HS. Investigations of treatment approaches aimed at reducing or harnessing global synkineses should consider that upper limb global synkineses are task specific and preferentially generated during grip exertions as compared to ankle exertions.

Possible explanations for this task specificity are difficult to propose as the underlying neurophysiological mechanisms involved in global synkineses are still unknown. However, it was recently suggested that global synkineses result from: 1) increases or modifications in motor irradiation due to loss of supra-spinal control and / or, 2) changes in processing at the motoneuronal or interneuronal levels (7).
Motor irradiation is a phenomenon defined as the diffused radiation of a voluntary effort to other muscles (53). It occurs regularly during extreme effort in normal subjects (11, 19, 21, 27, 44) and pathological subjects (13, 30, 35, 41). It has been suggested that some stroke patients may lack the spatial and temporal patterning from supra-spinal control systems to block motor irradiation (53). Studies of motor irradiation in healthy subjects indicate that it is generally widespread within the body (18, 44), more prevalent in muscles used to stabilize the body (42) and occurs when the voluntary effort is maximal (54). The level of muscle overflow or motor irradiation reported in the literature varies from 10% to 20% of the maximal EMG (19, 36). Authors cite conflicting levels of motor irradiation depending on the type of resisted exercise. Increases in maximal strength and cardio-vascular performance in contralateral or ipsilateral untrained muscles following one limb strength or cardio-vascular training have been attributed to motor irradiation (15-17, 28, 29, 31, 33, 37, 38, 43, 49-52).

From these observations, it was postulated that during efforts requiring high levels of exertions on the non-affected side, irradiation of the voluntary command triggered upper limb GS on the paretic side. This phenomenon and its effects could be facilitated by plastic changes occurring in the central and peripheral nervous systems after a stroke. Indeed, there is growing evidence that recovery from paresis of central origin is mediated by a reorganization of the remaining functional pathways. This reorganization involves among other things, an activation of existing or novel ipsilateral descending pathways through unmasking (14, 22-25, 40). Motor irradiation could thus be facilitated after a stroke as a consequence of increased use of these emerging motor pathways.
Another mechanism may be the absence of change in the level of irradiation itself but may be an increase in the excitability of interneurons or motoneurons on the affected side due to the loss of synaptic connections. Motor irradiation that would normally be insufficient to trigger motoneuronal or interneuronal actions potential would, because of lowered activation thresholds, result in involuntary activity of contralateral muscles. From the results of the present study, it is clear that upper limb global synkineses in HS are preferentially elicited during contralateral grip tasks compared with ankle tasks. This suggests that, in accordance with the task executed, the magnitude of the irradiation generating global synkineses appears to be specific to the limb executing the efforts or movement.
CONCLUSION

The purpose of this study was to use surface electromyography to characterize the intensity and pattern of global synkineses in HS during various maximal isometric exertions. The results suggest the distinct presence of two complementary types of GS: those that can be elicited indiscriminately during ankle exertions on both the affected and non-affected sides and those observed during a contralateral prehension task. Comparisons of upper limb global synkineses recorded during each different task showed that they were preferentially elicited during contralateral grip exertions. This task specificity may reflect the neurophysiological mechanisms involved in the generation of GS in HS.
REFERENCES


FIGURE CAPTIONS

FIGURE 1. Illustration of global synkineses observed in hemiparetic subjects during resisted exertions a) grip exertion, b) non-affected ankle exertion in dorsi-flexion, c) non-affected ankle exertion in plantar-flexion, d) affected ankle exertion in dorsi-flexion.

FIGURE 2. Mean involuntary EMG activities (% of EMG max) recorded in biceps brachii [BB], brachioradialis [BR], triceps brachii [TB] and flexor digitorum [FD]. These activities were recorded on the paretic side of hemiparetic subjects (n=11) or alternate limbs of normal subjects (n=10) during contralateral non-affected hand grip [NAH], non-affected ankle dorsi-flexion [NAADF], non-affected ankle plantar-flexion [NAAPF] and ipsilateral affected ankle dorsi-flexion [AADF] and affected ankle plantar-flexion [NAADF].