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The Upper Extremity Function of Stroke Patients in the View of Surface Electromyography

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ABSTRACT

Background: Movement of a healthy organism is characterized by a high degree of variability performance of a movement task. In a situation of a motor control lesion, mainly due to neurological disease, occurs in varying degrees to a fixed musculoskeletal manifestation. There are manifesting in a limiting responsiveness to changing external or internal conditions during the task oriented physical action.
Objective: To determine differences in muscle activity and variability between a muscle synergy of acral and proximal muscles during reach and grip in healthy subjects and stroke patients.
Methods: The experimental group consisted of 24 probands after ischemic stroke (ictus) with right-sided hemiparesis. The control group consisted of 30 healthy subjects. Muscle activity was recorded using surface electromyography during the performation of selected types of grips of cylindric and spheric objects. The differences in the area under the curve record of individual muscles between the experimental and control group were statistically evaluated using the t-test for independent groups. The relationship between the activity of the muscles of the forearm and shoulder girdle muscles was assessed using Spearman's correlation coefficient for non-parametric values.
Results: There were the significant differences in the size and number of statistically significant correlations distal and proximal arm muscles. In stroke group was found significantly lower activity m. pectoralis major and higher activity m. trapezius. At the same time the prevailing high correlation m. pectoralis major and extensor wrist and fingers, unlike the group of healthy subjectss, when the correlation distal and proximal muscle groups appeared at random, in a lesser extent and frequency.
Conclusions: The results indicate a reduction in variability of muscle activity during grasp function of stroke patients. To compensate the lack of activity of acral muscles becomes relatively fixed „co-activation" with selected proximal muscles.

KEY WORDS

muscle synergy, stroke, ictus, hand, manipulation, reaching, grasp

INTRODUCTION

Variability and flexibility of movements of the upper limb is the result of mechanical redundancy of the musculoskeletal system. Redundancy can be understood as the existence of a large number of combinations of individual joint movements (1). Bernstein has defined redundancy as a situation, when more than one signal may lead to the same trajectory. And vice versa,the same motor signal may lead to different movements in the case of changed initial conditions or variations of the external environment during the movement (2). Bernstein linked redundancy problem with the concept of synergy, which he considered as a system of redundant degrees of freedom (degrees of freedom, hereinafter DOF) to achieve lower variability or higher functional stability of the motor output (3).

The term synergy includes kinematic, kinetic and electromyographic models of variables simultaneously activating during the action or through repeated attempts (4). In muscle synergies all muscles are tightly bound to the extent that a central coordinating signal activates all the muscles in synergy. If the requirements of the task become different, control signal sets change of synergies leading to a parallel change in all muscles bound with this synergy (5).

Latash (5) does not consider the amount of DOF problem of CNS, but a luxury, which allows the control center to ensure stability and flexibility for solution of particular components of each task and adjusting deviations. His ambition is to change the designation „The problem of motor redundancy“ to „Benefits of motor abundance“ (6).

Abundance allows effecting a movement different ways in a system, allows adaptation to changed conditions (1). Due to the abundance a simultaneous implementation of multiple tasks is enabled at the same time without mutual influence. In other words: without motor abundance it would be impossible to manage the transport of the hand and its orientation to an object simultaneously, without these two components of movement influencing each other (7).

To describe the manner of movement of the pacient after stroke is frequently used the term pathological synergy due to the limited and inflexible connection of movement of the segments during the movement. Latash and Anson (7) emphasize that it is necessary to analyze two characters of such synergies, namely sharing and error compensation. Sharing is meant in the sense of contribution of elementary variables to the performance variables and compensation is meant in the sense of coordinating changes in the basic variables. Brunnströmová already described compensation of lesion of the central nervous system (hereinafter CNS) using the concepts of flexor and extensor synergy (8).

The inability of isolated muscle activity and pathologically reduced amount of available synergies of patients with hemiparesis reduce the ability to execute the movement of the upper limb in a desired trajectory.On the other hand, just a recruitment of DOF additives, for example a hull within a range, can contribute to improved performance. Injured CNS still has the ability to solve problems of redundancy e.g. recruiting a hull as the optimal compensation strategy for improving the movement output. Patients after stroke, or cerebrovascular accident (hereinafter CVA) with limited return of upper limb function include the hull into outreach activities, which allows to extend the range and functional capabilities of paretic limb (9).

OBJECTIVE OF WORK

The aim of the experiment was to determine, what is the variability of muscle synergies of acral and proximal muscles within range and grip in healthy individuals and in patients with hemiparesis. To record using surface electromyography (hereinafter SEMG), what is the level of activity of the arm muscles in patients after stroke during functional activities in comparison with healthy individuals.

METHODOLOGY

Objectives of the study

Determine differences in the degree of involvement of muscles of the shoulder girdle and forearm between the group of patients with hemiparesis and a control group of healthy subjects during grip function.

Determine differences in correlations of activity of proximal and distal muscles during reach, grip and moving of four items between the group of patients with hemiparesis and control group.

Group characteristics

Experimental group of n = 24 probands with a history of stroke, 16 men and 8 women. The average age of 52.4 years (31–68 years), average time since the inception of CVA 23.6 days (15–55 days). Ischemic lesion of the left middle cerebral artery, with paresis of the right, the dominant upper limb. Dominance was assessed by asking for feature writing and accurate throw before the onset of disease. The rate of spasticity in all probands up to grade 1 according to the modified Ashworth range. Control group of n=30 probands, 22 women and 8 men. The average age of 36,3 years (range 23–52 years). There were no injuries of dominant right arm history of probands. Dominance was assessed by an accurate throw. All persons were informed of the process of measurement and signed a written consent to participate in the study. The study was approved the Ethics Committee of FZV UP Olomouc under No. OP-046/ 2012/FZV of 6. 2. 2012.

The measurement process

Probands took up position sitting on a chair, facing the table in an upright body position with the forearm lying loosely on the table. A mark at a distance of 20 cm from the edge of the table was marked as well as a mark at a distance to the length of the upper limb of the proband without hull rotation with extended elbow. Probands were asked to grip the subject positioned closer to them and to relocate it to distant mark. Used types of grips: cylindrical and spherical. Used items: cylinders with a diameter of 5.5 cm and 7.5 cm, spheres with a diameter of 4.5 cm and 11 cm. This procedure was repeated three times for each of the objects, the average of three experiments was used for the evaluation.

Scanning of the electrical activity of muscles was performed using 8 channel surface electromyograph (Myosystem, Noraxon). Scanned muscles: mm. extensores antebrachii (EA), mm. flexores antebrachii (FA), m.infraspinatus (INF), m. trapezius pars descendens (TD), m. latissimus dorsi (LD), m. deltoideus pars anterior (DA), m. serratus anterior (SA), m. pectoralis major (PM).

SEMG signal processing and statistical data processing

For evaluation and statistical processing the grip was divided into three parts: reach (from start of movement to reach of subject), actual grip of subject (fully grip of the course with all fingers) and distancing of the subject (to labeled distanced place on the table). The record was modified using EKG reduction, smoothed and rectified, processing at step of 50 ms. From the mean of three experiments for each subject it was calculated the area under the curve recorded and subtracted the surface of standstill record. Matlab software was used for mathematical processing. The values of both sets of data were compared using the t-test for independent groups. Statistical significance was set at value p = 0.05. For statistical data processing the Statistika CZ software, version 10 was used.

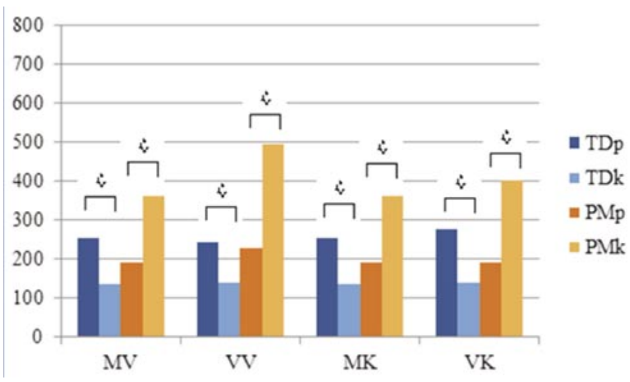
To evaluate the relationship between distal and proximal muscles of the upper limb during the various stages of grip of objects, we used the calculation of multiple regression in Matlab software.

Multiple regression follows the linear dependence between two or more variables. The first set of evaluation of depending pairs formed integral values (area under the curve of record) of mm. extensores antebrachii and gradually all the proximal muscles, and a second set pairs the values of the integral of mm. flexores antebrachii and all proximal muscles. The strength of the relationship of dependency was evaluated using the Spearman correlation coefficient for nonparametric values. The statistical significance of the correlation was determined at the level p = 0.05. For statistical data processing the Statistika CZ software, version 10 was used.

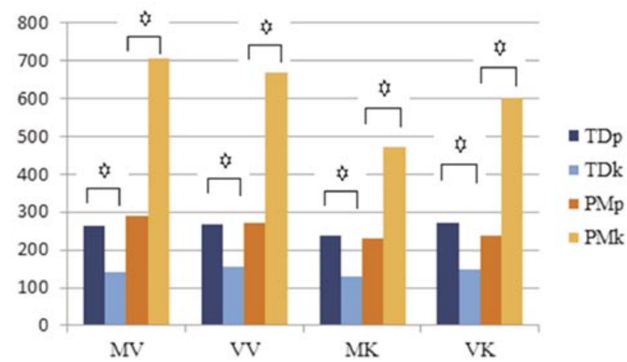
RESULTS

The resulting comparison of the areas under the curve of record shows statistically significant differences between sets in all phases of the test. Statistically significant changes in activity at reach and grip of all subjects, at the level of statistical significance p = 0.05, is demonstrated in m. trapezius pars descendens in terms of higher activity in the experimental group, and conversely lower activity at the level of statistical significance p = 0.05 is demonstrated in m. pectoralis major at reach and grip of all subjects. The same muscles exhibited the same trend at the stage of manipulation of object (distancing from the proband), as the statistically significant difference was found at that stage only in cylindrical objects.

Graphs 1 and 2 show an illustrative comparison of values of the integrals (area under the curve of record as the representation of rate of muscle activity) of muscles exhibiting statistically significant differences in particular tests between the two sets.



Graph 1 Displaying the area under the curve of record (integral uV) of m. trapezius pars descendens and m. pectoralis major during reach



Graph 2 Displaying the area under the curve of record (integral uV) of m. trapezius pars descendens and m. pectoralis major during grip

Legend to graphs 1 and 2: TDp – m. trapezius pars descendes patients, TDk – m. trapezius pars descendes control group, PMp – m. pectoralis major patients, PMk – m. pectoralis major control group, SC – small cylinder, LC – large cylinder, SS - small sphere, LS – large sphere. Statistically significant correlations at the level p = 0.05 are marked*.

Table 1 Summary of the multiple regression correlation coefficients. All mentioned correlation coefficients showed statistical significance at the level (p = 0.05). The correlation coefficient of the two sets is listed: forearm flexor with all proximal muscles and extensor forearm with all proximal muscles for given activities and objects (SC small cylinder, LC large cylinder, SS small sphere, LS large sphere)

	Experimental set (patients with hemiparesis)		Control group (healthy subjects)	
	mm. flexores antebrachii	mm. extensores antebrachii	mm. flexores antebrachii	mm. extensores antebrachii
m. trapezius descendens	---	---	---	---
m. deltoideus anterior	---	---	Reach of LS (r = 0.4472) Distancing of SC (r = 0.3687)	---
m. pectoralis major	---	Reach of LC (r = 0.6637) Grip of SC (r = 0.7569) Grip of LC (r = 0.7954) Grip pf LS (r = 0.7727) Distancing of LC (r = 0.9537)	---	---
m. infraspinatus	---	Reach of MK (r = 0.6142)	Distancing of MV (r = 0.4101)	---
m. serratus anterior	---	---	---	---
m. latissimus dorsi	---	---	Distancing of MK (r = -0.3508)	---

The results of multiple regression indicate changes in synchronous activities and acral-girdle muscles. Summary of statistically significant correlations at the level p = 0.05 in both groupsis given in Table 2. Experimental group shows a higher overall number of statistically significant correlations and their higher values, and relatively stereotypically in pair of m. extensores antebrachii and m. pectoralis major in the phases of reach, manipulation, but especially static grip in all subjects.

The control group shows higher variability of dependence of two variables. Statistically significant correlations appear only sporadically. In reach and grip in only one of 48 evaluated situations, in manipulation of object (distancing from subject) it was detected in two cases: acral m. flexores antebrachii with the front portion of deltoid and m. infraspinatus when handling small cylinder.

DISCUSSION

Upper limb compared to lower limb exercise more variable and complex activity. There is no set standard activity for it for evaluation, such as walking for leg, which is both cyclic and at the same time has clearly defined limits of performance (10). For evaluation of arm activity in patients with hemiparesis, in professional studies is most commonly used the assessment of scope and grip (1, 11), studies on kinematic motion analysis prevail (12), the surface EMG is used less (13). Results of studies of outreach activities terminated with grip using kinematic analysis agree that movement of the arm in stroke patients is slower compared to healthy probands, with limited elbow extension and flexion of the shoulder and greater forward movement of the hull (12, 1, 11), movement of the arm is less smooth, track of embodiment is more variable, with multiple motion errors (1). It is observed that the outreach arm movement performed with elbow flexion is associated with a simultaneous increase in external rotation and abduction of the shoulder, called as flexion synergy by the authors. Conversely sufficient extension at the elbow joint is connected to the adduction in outreach activities and internal rotation of the shoulder, called as extensor synergy (14).

Reasoning for the choice of SEMG in comprehensive evaluation of arm movement dysfunction after stroke is the fact that muscle activity reflects the activity of motoneurons. Therefore, analysis of muscle activity can best provide an understanding of functional neural deficit after stroke. Neural lesion changes cortical activation patterns of muscle synergies, leading to motor dysfunction of the affected limb. In this situation, the concept of synergy rather associated with stereotypical movement, when a limb is losing independent control of joints and thus limits the individual in coordination and flexibility of movement patterns (15). This confirms the abovementioned kinematic analysis as well as our study, when it is evident certain stereotypisation in involvement of groups of acral and proximal muscles in strong links in implementing the various phases of grip function. Michaelsen et al. (16) reached different results in assessing muscle activity during reach and grip, following higher activity of m. pectoralis major during the entire movement. Also McCrea et al. (17) described that during the reach stereotypically appeared increased activity of m. deltoideus pars lateralis and m. pectoralis major in patients after stroke, to compensate for the lack of activity of primary agonists, in this case m. deltoideus pars anterior. Consistent with our study, there was observed a significant activity of m. trapezius pars descendens (superior) by authors Rueda et al. (18), which in their experiment increasingly activated compared to the control group, especially in the initial phase of the movement of reach, grip and drink from a glass.

CONCLUSION

Surface electromyography complements the comprehensive evaluation of physical dysfunction of hemiparetics, in our case specifically grip function. The evaluation pointed to a significant decrease in muscle activity of m. pectoralis major in the majority of tested situations, which is compensated by an increase of muscle activity in the upper part of m. trapezius at the level of statistical significance.

At the same time it is important the increase in the number of significant correlations of acral and proximal muscles, with stronger binding and lower variability compared to the control group. Maximum uniformity of this occurred in the proximal muscles links (manily m. pectoralis major) with wrist extensors. Both muscle groups showed lower values of area under the curve of record representing the rate of muscle activity. Their strong bond during all phases of grip function suggests one of the ways of change the neural control resulting in compensation for their inadequate activities during the grip function.

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