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Premovement Silent Period of Erector Spinae and Reaction Times of Bulky Muscles in Ballistic Standing-up Movement

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ABSTRACT. The appearance rate of premovement silent periods (PMSs) of the erector spinae and EMG-reaction times of the obliquus abdominis and quadriceps femoris were examined during fast ballistic standing-up movement in the normal adults and hemiplegics. The average appearance rate of PMSs in hemiplegics was lower than in normal subjects, but no significant laterality was observed in either groups. Reaction times of trunk muscles also showed no significant laterality in either the normal subjects or the hemiplegics. Considering the relation between the appearance rate of PMS and the motion velocity, the PMS did not seem to reflect the central processing efficacy itself, which can be evaluated by reaction time measurement. Electromyographic study of the PMS may provide an indicator of the central coordination mechanism of the trunk and extremities.

Key words : Premovement silent period — Reaction time — Trunk muscle

For the initiation and execution of fast ballistic voluntary movements of the body, some neuronal mechanisms are thought to set the tonic stabilizing activity of the concerned muscles against an impending phasic one. With respect to this function of the central nervous system, the so-called Premovement Silent Period (PMS) is recently an object of attention.[1–4]

In our previous studies of the PMS of the quadriceps femoris muscles,[5] we found that the appearance rates of PMSs are lower in hemiplegics than in normal subjects especially on the affected side. Moreover, we noticed that PMSs also appeared in the back muscles (Erector spinae) at fairly high rates during ballistic standing up movement.

There have been few reports about the PMS of trunk muscles. In this study, we recorded the EMG of the trunk muscles and quadriceps muscles during standing up movement, and analyzed the conditions for appearance of the PMS in relation to the reaction times of bulky muscles.

MATERIALS AND METHODS

The experiments were performed on six normal adults aged from 20 to 29 years (average age : 22.5 years) and nine hemiplegics aged from 17 to 60 years (average age : 40.6 years) including four lt. hemiplegics and five rt. hemiplegics. All of the hemiplegic subjects were mild cases without any

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complications such as aphasia, mental deteriolation or severe sensory defects.

The Brunstrom recovery stages of these patients were higher than grade-IV, and the patients could stand up and walk independently without a cane or braces.

The subject sat on an adjustable training chair (Lift-ride chair) lightly with his feet about 30 cm apart in front of the chair which was adjusted to keep the knee joints flexed at 90 degrees. Then, by verbal command (warning signal), he was instructed to gradually lean forward, keeping the spinal column straight, until the center of gravity of the body fell on the center of the feet. In this position, the subject was asked to take care not to prepare to use the quadriceps muscles. After an acoustic signal occurring 2∼5 sec thereafter, the subject stood up as fast as possible (Fig. 1). Electromyograms were recorded from the obliquus abdominis muscles (on the anterior axillar line just below the hypochondral margin), erector spinae muscles (at the L_2 level), and vastus lateralis muscles using disc surface electrodes taped over the skin. A Polgon goniometer was set on the lower extremity of the intact side (on the rt. leg of normal subjects and lt. hemiplegic subjects, and on the lt. leg of rt. hemiplegic subjects) to detect the initiation of knee motion. After several preliminary executions, twenty trials of ballistic standing up movements were performed by each subjects.

All signals were recorded on magnetic tape and fed into a memory scope, where EMG-reaction times and reaction times of knee motion were read on a 10-msec scale. Concerning the obliquus abdominis muscles, the raw EMGs were rectified and averaged by an integrator (time constant : 0.1 sec) to read the beginning points of EMG-bursts,[6] because preparation to use the muscles could not be eliminated easily by the majority of the subjects (Fig. 2).

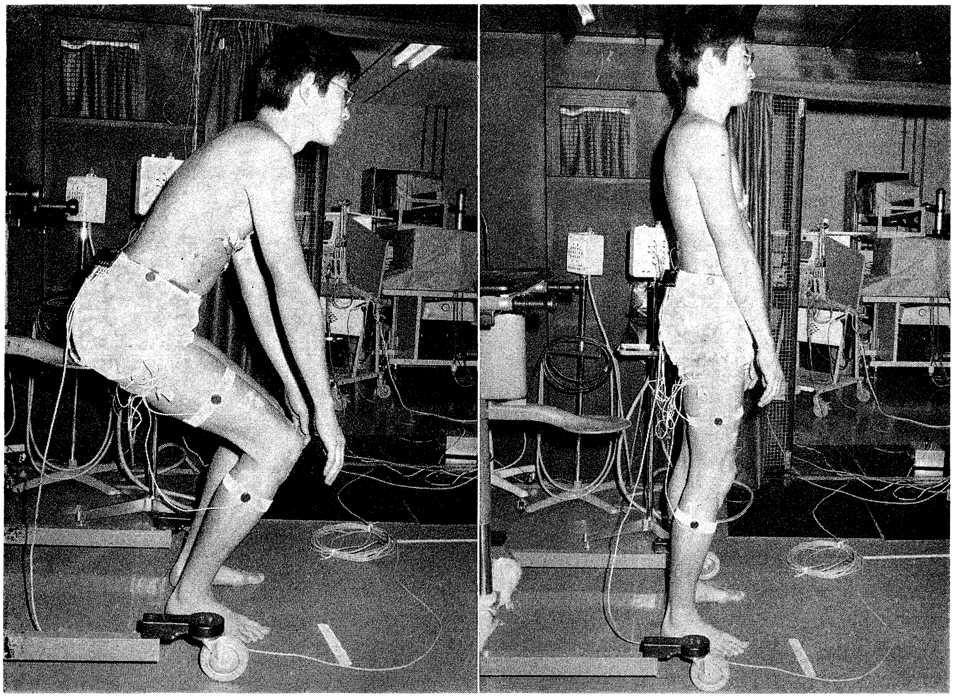

Fig. 1. The initial position (left) and the fina position (right) of the task.

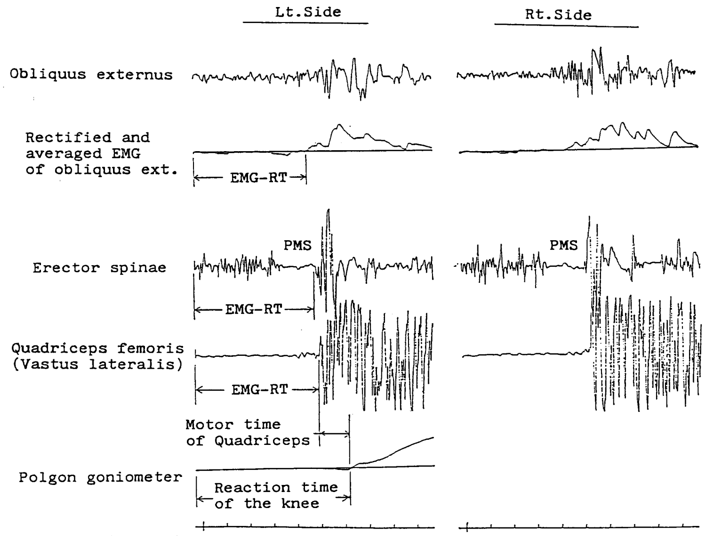

Fig. 2. Polychannel recording of a single trial by a lt. hemiplegic person.

RESULTS

PMS appearance rates

Appearance rates of the PMSs of erector spinae muscles in each group are illustrated in Figure 3. The average appearance rates of the lt. erector spinae were 75% in normal subjects, 48% in lt. hemiplegics, and 44% in rt. hemiplegics. The values of rt. erector spinae muscles were 73%, 58% and 41% respectively. The frequency of PMSs was not significantly different between sides of the body in any group (Table 1).

Reaction times of knee motion, and motor times of the quadriceps femoris in relation to the appearance of the PMS of the erector spinae

As shown in Figure 4, reaction times (RT) of knee motion in hemiplegic patients were longer and more variable than in normal subjects. To test if there were correlations between PMS appearance and the speed of motion, all the trials in each group were divided into two classes according to the appearance or nonappearance of a PMS of the erector spinae, and then, motor times of intact legs and knee-RTs of each class were compared. As seen in Table 2, there was no significant difference in motor time of the quadriceps or in knee-RT between the two classes in any group (by Student's t-test).

Laterality of EMG-RT of each muscles

A paired t-test was performed on the data of each subject to compare the EMG reaction times of each muscle on either sides of the body. Two hemiplegic subjects exhibited significant difference according to which side the EMG-RT was taken, but only in the quadriceps femoris muscles. In other subjects, no significant laterality was found in any muscle.

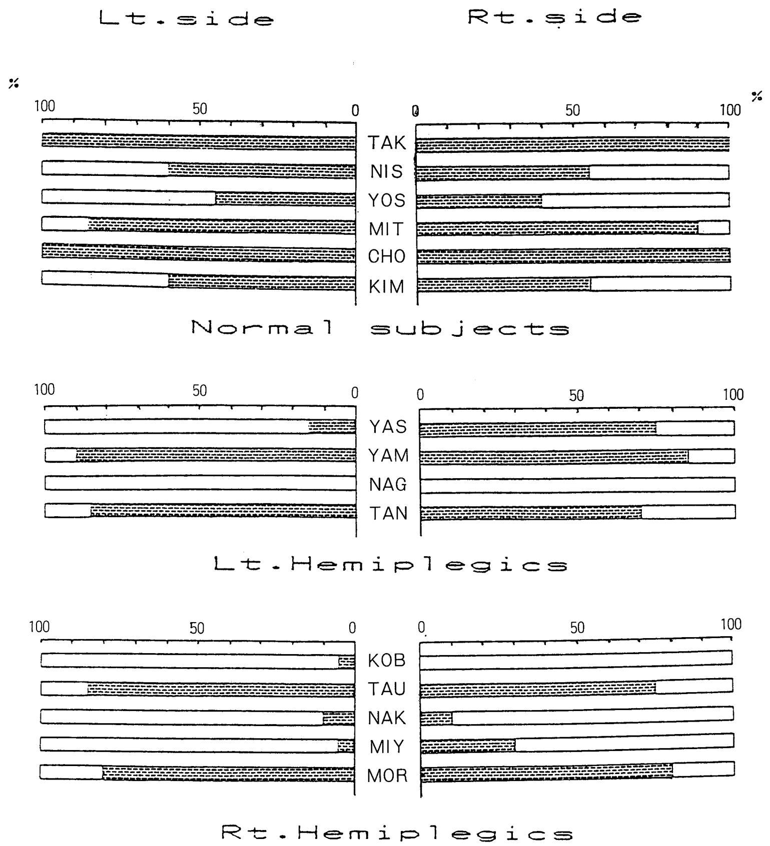

Fig. 3. Appearance rates of PMSs of the erector spinae. Shaded area represents the percentage of appearance in each subject.

TABLE 1. Cross table showing the total numbers of trials in which a PMS appeared or did not appear in each side of the erector spinae in each group. The frequencies of PMS appearance were significantly lower in hemiplegics than in normal subjects, but no significant laterality was observed in any of the groups.

	Normals		Lt. hemiplegics		Rt. hemiplegics	
Number of trials in which PMS appeared	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
	83	80	39	47	35	37
Number of trials in which PMS did not appear	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
	37	40	41	33	65	63

1) Comparisons of PMS-appearance between the groups
Normals vs Lt. hemiplegics : $\chi^2=8.20$ ($p<0.01$)
Normals vs Rt. hemiplegics : $\chi^2=37.64$ ($p<0.01$)

2) Comparisons of PMS-appearance between lt. side and rt. side
Normal subjects : $\chi^2=0.17$ ($p>0.50$)
Lt. hemiplegics : $\chi^2=1.61$ ($p>0.10$)
Lt. hemiplegics : $\chi^2=0.09$ ($p>0.50$)

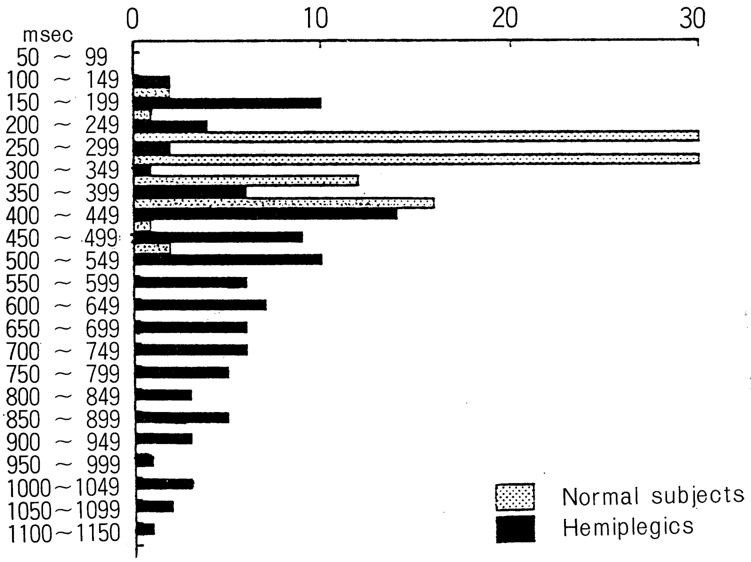

Fig. 4. Histogram of reaction times of knee joint (abscissa : number of trials).

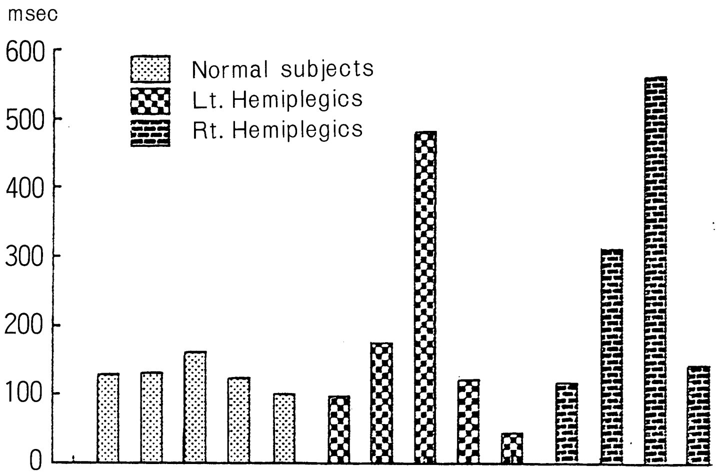

Fig. 5. Averaged time-gaps between the onsets of the EMG-burst the obliquus abdominis and of knee motion of the non-affected limb.

The order of initiation of muscle activities in the standing-up movement

During the standing-up movement performed in this study, the activities of the obliquus abdominis muscles preceded the activities of the quadriceps muscles in the majority of trials in all subjects. In general, muscle activity started in the obliquus abdominis, then progressed to the erector spinae, and quadriceps femoris in that order. The time lag from the beginning of the obliquus abdominis activity to the beginning of the quadriceps abdominis activity seemed to be longer in hemiplegics than in normal subjects (Fig. 5).

TABLE 2. Averaged reaction times (RT) of knee motion and motor times (MT) of the quadriceps femoris in relation to the appearance of the PMS of the erector spinae. No significant differences were observed between classes of trials in which PMS appeared or did not appear. Comparisons were done by confidence intervals. (degree of confidence : 0.90)

		RT of knee motion	MT of quadriceps
Normals	PMS (+)	328 ± 61	70 ± 34
	PMS (−)	345 ± 70	93 ± 34
Lt. hemiplegics	PMS (+)	467 ± 261	86 ± 36
	PMS (−)	451 ± 257	30 ± 32
Rt. hemiplegics	PMS (+)	623 ± 137	145 ± 87
	PMS (−)	724 ± 335	153 ± 96

DISCUSSION

During the execution of fast movement, a premovement silent period occurs not only in "reaction time situations" but also in self-paced voluntary movements.[7] This phenomenon is known to correlate with the development of motor coordination or "movement skill".[8,9]

Yabe *et al.* have proposed that the PMS could be attributed to some neural mechanisms which change the tonic excitation of alpha-gamma linkage into phasic excitation of a pure alpha route.[2,3] Recently, Conrad *et al.* reported that there was a positive relation between the duration of PMS and the integral of the first agonist burst during ballistic elbow movements, suggesting that PMS would bring all motoneuron into a non refractory state, enabling all available motoneurons to be ready to fire at the same moment.[7]

In extremities. the PMS usually appears in both agonists and antagonists at the same time,[2,7] and hemiplegic patients show a significantly lower appearance rate than normal subjects, especially in the affected limbs.[5,8] In the present study, we recorded electromyograms of trunk muscles in a reaction time situation. PMS appearance was observed in the erector spinae, but not in the obliquus abdominis, although sustained tonic activities prior to the ballistic movement were maintained in both muscles. In the hemiplegic patients, appearance rates of the PMS of the erector spinae on affected sides were not significantly lower than on intact sides, while they both were lower than the rates in the normal subjects.

According to the current concept of PMS, the appearance of this phenomenon depends on a supraspinal mechanism.[2,3,7,11] The lack of laterality of the PMS appearance rate in hemiplegic patients observed in this study is in contrast to the finding of our previous study[5] which showed significant difference between sides in the quadriceps femoris of hemiplegic patients. These findings bring to mind the analogous results concerning reaction times of limbs and trunk muscles recently reported by Nakamura[12] and Ebara,[13,14] and may support the hypothesis that trunk muscles near the midline of the body are under control from both cerebral hemispheres.

Till today, the role of the PMS was believed to augment the acceleration of movement,[7,15,16] but as shown in Table 2 in this study, the appearance of the PMS seems to reflect neither the simple speed of motion itself nor the central processing efficacy which can be evaluated by reaction times.[10,17]

Nevertheless, despite the definite importance of trunk muscle control in mass movement of the body,[18-20] there have been few good methods developed up to now by which we can objectively evaluate the coordination of trunk and limbs. Electromyographic recordings of the PMS may be of value in estimating central control mechanisms of the trunk and extremities.

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