Loss of Reaction Time Specificity for Movement Direction in Parkinson’s Disease

RYUICHI NAKAMURA, JOSE ALVIN P. MOJICA, YOSHIAKI YAMADA and FUSAKO YOKOCHI*

Institute of Rehabilitation Medicine, Tohoku University School of Medicine, Miyagi 989-68, and *Department of Neurology, Juntendo University School of Medicine, Tokyo 113

NAKAMURA, R., MOJICA, J.A.P., YAMADA, Y, and YOKOCHI, F. Loss of Reaction Time Specificity for Movement Direction in Parkinson’s Disease. Tohoku J. Exp. Med., 1989, 158 (1), 9-16 — Electromyographic (EMG) reaction times (RTs) of the right biceps brachii muscle and its integrated EMG (iEMG) from the onset until 50 msec after the start of activities for elbow flexion and forearm supination in the condition with or without warning signal were examined in seven patients with Parkinson’s disease and seven age- and sex-matched normal subjects. In the control group RT of forearm supination with warning tended to be faster than that of elbow flexion and the reverse occurred without warning, and iEMG of forearm supination were significantly small compared to those of elbow flexion in each condition. In the Parkinson group both RT and iEMG of elbow flexion were nearly the same as that of forearm supination regardless the presence or absence of warning signal, indicating the loss of RT and iEMG specificity for the two direction of movement in Parkinson’s disease. — biceps brachii; EMG; movement direction; Parkinson’s disease; reaction time

Among the primary symptoms of Parkinson’s disease, impairment of voluntary movements is an important cause of disability. Changes in arousal level (Pullman et al. 1988), faulty transmission of motor commands (Angel et al. 1970), and a failure of systems functioning to provide outputs underlying high speed movements (Evarts et al. 1981) have been implicated as causes but conclusions are still unclear. Thus, studies geared toward the understanding of movement initiation and control by comparing the performances of patients with Parkinson’s disease to those of normal subjects are being done to gain further insight into the mechanisms underlying the impairment.

Previous studies on electromyographic reaction time (RT) of the biceps brachii muscle in normal subjects have shown that RT of forearm supination was faster than that of elbow flexion for simple RT conditions and that the effect of warning signal to reduce RT was more remarkable on forearm supination than
elbow flexion (Nakamura and Saito 1974; Kasai et al. 1982). Results from these studies indicate that both the direction of movement and the timing of warning signal are significant variables relating to the motor output process and that different motor programs govern elbow flexion and forearm supination. Mojica et al. (1988) pointed out in the simple RT study with or without warning signal that integrated EMGs (iEMGs) during the first 50 msec after the initiation of muscle activities for elbow flexion were larger than those for forearm supination. Moreover, with warning signal both iEMGs of flexion and supination were small compared to those without warning, indicating that the biceps brachii muscle normally exhibited a differentiation of motor response specific to the condition requirements and the direction of movements and that preparatory set conditioned by warning shortened RTs and suppressed EMG activities.

In Parkinson’s disease, prolongation of RTs have been reported (Yokochi et al. 1985; Yokochi and Nakamura 1988) and attributed to disorders in the two functional loops of the basal ganglia related to motor behavior, the complex and the motor loops (DeLong et al. 1983). In addition, the differentiation of RTs between elbow flexion and forearm supination is lost in Parkinson’s disease (Nakamura and Taniguchi 1980), suggesting a disorder of ‘programs’ of movement for which the basal ganglia and cortical motor centers play a crucial role. Then questions arise how preparatory set for elbow flexion and forearm supination is organized in patients with Parkinson’s disease and whether the presence of warning signal affects initial EMG activity of the two movement directions or not. The present study was done to answer the above questions and to better understand the pathokinesiology in the initiation of fast voluntary movements in Parkinson’s disease.

**Methods**

Seven patients, two males and five females, diagnosed as Parkinson’s disease ranging in age from 39 to 69 years (mean +/− S.D.: 55.0+/−10.8) and seven control subjects, three males and four females, aged from 32 to 61 years (48.3+/−10.9), with no history of neurological disorder participated in the study. The patients were with stage II to III clinical disability based on Hoehn and Yahr’s classification (1967). Each of the patients was taking anti-Parkinson medication according to schedule at the time of testing. All patients could walk independently and manage several hand activities, although they had some difficulty in activities of daily living (ADL). All subjects were right-handed by self report and gave informed consent.

During a single experimental session, the subjects sat comfortably on a specially designed chair with eyes closed, keeping the trunk upright and the shoulders slightly flexed. The forearms rested on arm holders with the elbow angles at 70 degrees flexion and the forearms in midposition. The subject was asked to respond as fast as possible to a command tone signal (1,000 Hz, about 100 dB, 50 msec duration) provided by a loudspeaker situated above the subject with either right elbow flexion or forearm supination under two conditions, with or without warning signal. The tasks were 1) elbow flexion with warning, 2) elbow flexion without warning, 3) forearm supination with warning, and 4) forearm supination without warning. In the ‘with warning signal’ condition, the command tone
signal was presented about 2 sec after a verbal warning, ‘ready’. The intertrial intervals were from 20 to 30 sec. In the ‘without warning signal’ condition, the command signal was retained but the warning was omitted. The intertrial intervals were from 15 to 60 sec. At least two blocks of 5 or 6 trials for each task counterbalanced among the subjects were taken. To familiarize the subject with the experimental design, several practice trials were performed prior to the experimental run.

EMG activity of the right biceps brachii was bipolarly recorded through surface electrodes attached 2–3 cm apart on the muscle belly. After amplification with a bioelectric amplifier (−3 dB, 16–1,000 Hz, AB621G, Nihon-Kohden, Tokyo) the EMG signal was recorded (DFR3515, Sony, Tokyo) and processed with a digital computer (PC-9801VM2, NEC, Tokyo) via A/D converter. RT, defined as the latency from the tone signal to the onset of EMG activities, was measured on a display (PC-8853N, NEC, Tokyo) in msec. The means and SDs of RTs in each task were computed. Raw EMG was full-wave rectified, and integrated every 1 msec. The means and SDs of integrated EMG values (iEMG) from 1 to 50 msec for each subject in each task were calculated and analyzed.

RESULTS

Table 1 shows the mean RTs of elbow flexion and forearm supination for the two conditions in each group. A three-way ANOVA (movement direction × condition × group) revealed that the main effect of condition was significant (p < 0.01). The interaction between movement direction and group was also significant (p < 0.05). Mean RTs of flexion and supination were significantly faster with warning than without warning signal for both groups (control: ps < 0.01; Parkinson: ps < 0.01, respectively). The mean RTs without warning tended to be longer in the Parkinson than in the control group (flexion: p < 0.05; supination: p < 0.1), indicating that the effect of warning to reduce RTs was remarkable in the Parkinson compared to the control group. Although the difference did not reach the level of statistical significance, the mean RTs in the control group showed that RT of forearm supination with warning signal tended to be faster than that of elbow flexion and the reverse occurred without warning. As shown in Table 1, RT of elbow flexion in the Parkinson group was nearly the same as that of forearm supination for each condition. Fig. 1 shows the regression line of RT for forearm supination to that for elbow flexion calculated in respect of warning conditions in the control group (with warning: y = 0.62x + 40.74, r = 0.92, p < 0.01; without warning: y = 1.29x − 42.32, r = 0.97, p < 0.01) and the

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<tr>
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<th>With warning</th>
<th>Without warning</th>
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<tr>
<td></td>
<td>Control</td>
<td>Parkinson</td>
</tr>
<tr>
<td>Elbow flexion</td>
<td>128.2</td>
<td>124.6</td>
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<tr>
<td></td>
<td>(31.8)</td>
<td>(27.9)</td>
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<tr>
<td>Forearm supination</td>
<td>119.9</td>
<td>124.0</td>
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<td>(21.3)</td>
<td>(26.6)</td>
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Parkinson group (with warning: $y = 0.78x + 27.44, r = 0.81, p < 0.05$; without warning: $y = 0.91x + 18.33, r = 0.97, p < 0.01$). One-way ANOVA revealed a significant difference between the slopes of the two regression lines, with and without warning, for the control ($p < 0.01$) but not for the Parkinson group. These results indicated that the effect of warning to reduce RT was greater on supination than on flexion in the control group, whereas the effect was the same on both elbow flexion and forearm supination in the Parkinson group.

Table 2 presents the means of iEMG values for the first 50 msec of activity. Three-way ANOVA (movement direction $\times$ condition $\times$ group) showed that the main effect of movement direction was significant ($p < 0.01$) and the interaction between movement direction and group was also significant ($p < 0.01$). In the control group iEMGs of forearm supination were significantly smaller than those of elbow flexion regardless of the presence or absence of warning signal ($p < 0.01, p < 0.05$, respectively). In contrast, with and without warning signal there was no difference of iEMG between elbow flexion and forearm supination in the Parkinson group. The movement direction had no effect on the specification of

| TABLE 2. Means and standard deviations (in parenthesis) of iEMG (arbitrary units) with and without warning signal in the control and Parkinson groups |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| With warning                                    | Without warning                                 |
|                                                 | Control                                        | Parkinson                                      | Control                                        | Parkinson                                      |
| Elbow flexion                                   | 45.6                                           | 30.2                                           | 49.5                                           | 25.3                                           |
|                                                 | (27.1)                                         | (15.1)                                         | (26.3)                                         | (13.8)                                         |
| Forearm supination                              | 21.3                                           | 26.3                                           | 26.4                                           | 28.4                                           |
|                                                 | (13.0)                                         | (19.3)                                         | (21.3)                                         | (25.9)                                         |
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iEMG in Parkinson’s disease. The regression lines of iEMG of forearm supination to that of elbow flexion in respect of warning conditions in the control group (with warning: \( y = 0.38x + 3.75, r = 0.80, p = 0.05 \); without warning: \( y = 0.68x - 7.52, r = 0.85, p = 0.05 \)) and the Parkinson group (with warning: \( y = 1.16x - 8.72, r = 0.91, p < 0.01 \); without warning: \( y = 1.69x - 14.27, r = 0.91, p = 0.01 \)) are shown in Fig. 2. Although there is a shift of the slopes to the right with warning, one-way ANOVA showed no significant difference in regression slopes of the iEMGs for each group between the conditions. However, between the control and Parkinson groups there were significant differences in the slopes with and without warning (\( ps < 0.05 \), respectively), corresponding to the loss of specificity in iEMG of both movements in the Parkinson group.

DISCUSSION

The main finding of the present study is the loss of differentiation of RT and iEMG for elbow flexion and forearm supination in patients with Parkinson’s disease.

According to Kinugasa et al. (1988), preparatory set for the two movements, elbow flexion and forearm supination, is sequentially organized: the selection of response movements in the early phase, the speed and steadiness of response timing in the midphase and the differentiation of each response in the last phase. In this study the subject knew the response movement and was able to perform the movement correctly as instructed. The warning signal shortened RTs of the biceps brachii muscle in both the control and Parkinson groups confirming previous studies (Kasai et al. 1982; Mojica et al. 1988) and the effect of warning to shorten RT was more remarkable in the Parkinson group than in the control (Yokochi and Nakamura 1988). With warning signal mean overall RT for the
two movements was not significantly different between the control and Parkinson
groups. However, in the absence of warning overall RT of the Parkinson group
tended to be long. These findings indicated that the warning signal evoked an
eexternally triggered phasic arousal response in both the control and Parkinson
groups resulting in the reduction of overall RTs but that without warning the
arousal level in the Parkinson group tended to be low compared to the control
group causing a prolongation of the RTs. With warning signal RT of forearm
supination in the control group tended to be faster than elbow flexion (Nakamura
and Saito 1974), and the reverse occurred without warning. The warning signal
enhanced the differentiation of RTs between the movement directions acting on
the last phase of preparatory set (Kasai et al. 1982; Kinugasa et al. 1988).
Unlike the control, there was a loss of specificity of RTs into either that of elbow
flexion or forearm supination in the Parkinson group regardless of the presence or
absence of warning signal. Patients with Parkinson’s disease were able to prepare
for the movement direction and timing of response but there was no temporal
differentiation of the two movements, suggesting that the last phase of response
preparation was impaired.

Romeny et al. (1982), also examining isometric contraction of the biceps
brachii muscle in normal subjects, reported that motor units with a high threshold
for elbow flexion tended to show a low threshold for forearm supination and vice
versa, indicating that motor units were recruited selectively and the input to the
motor neuron pool from higher centers differed for each movement. In this study
iEMGs of elbow flexion were large compared to those of forearm supination
regardless of the presence or absence of warning signal in the control group similar
to earlier findings (Mojica et al. 1988). In the Parkinson group there was no
difference of iEMGs between the two movements with and without warning, that
is, the specificity of iEMG for the movement direction was lost. In Parkinson’s
disease there occurs either a failure to distinguish recruitment characteristics, loss
of selectivity of motor units, or loss of selective motor response in the same muscle.

![Fig. 3. A model of central states in RT situation with warning signal. 'Formal' cells with excitatory (arrow) and facilitatory (circle) are used as components of the model. Excitatory cells relay impulses and facilitatory cells speed up the transmission in the excitatory cells. (Modified from Hongo et al. 1981).](image-url)
The present study also suggested that two systems, one involving cognitive/sensory and the other motor processes, were influenced by the warning signal. Fig. 3 presents a simple model circuit conceptualized by Hongo et al. (1981) that may further elucidate the present results. This system has no anatomical substrates at present but is based on recent studies of central processing for motor initiation (Glickstein 1972; Requin et al. 1977; Brooks 1986). Assume that in normal subjects the central preparatory system is in a moderate state of arousal in which two ‘formal’ cells (P1, P2), after receiving warning signal, activate a cell (S) which receives the command signal and a cell (M) which produces the motor response, the latter two constituting the association system. Facilitation from cell P1 to S activates the cognitive/sensory processes and shortens overall RTs. In contrast, facilitation from P2 cell to M cell enhances the differentiation of the response movements thereby producing specificity of RT and iEMG for either elbow flexion or forearm supination. On the other hand, the absence of warning signal results in a low arousal level compared to the condition with warning and a decreased facilitation from cell P1 to S thereby bringing about the prolongation of overall RTs. In addition, RT and iEMG differentiation of the two movements occurs but less pronounced. Applying the above model to the performance of the Parkinson group in this study, it is suggested that facilitation from P1 cell to S cell is intact so that the warning signal increases arousal level of patients with Parkinson’s disease but the function of M and possibly P2 is definitely impaired, which results in the loss of RT and iEMG specificity for the two directions of movement.

Acknowledgments

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References


