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Fast Repetitive Force Changes in Hemiparetic and Cerebellar Patients*

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Summary. A method for the continuous registration of rapid isometric force changes was investigated in 24 healthy control persons, 10 hemiparetic patients and 10 cerebellar patients. Though the selection of both patient groups involved comparable deficits with respect to the number of force changes attained, the analysis of the underlying force-velocity patterns revealed considerable differences in the performance of hemiparetic and cerebellar patients. Hemiparetic patients showed gross deficits in both the force increasing and decreasing phases. In contrast to this, most cerebellar patients were able to release force as fast as normal controls, while marked slowness was only found for the force increasing phases.

Key words: Force control – Motor disorders – Hemiparesis – Cerebellum

Introduction

A significant decrease in alternate motion rate is often the first sign suggesting a lesion of the CNS (van Allen 1969). However, a perceptible slowness may result from a wide variety of causes. Succession deficits are found with lesions of the basal ganglia, the sensorimotor cortex, the corticospinal tracts (Walshe 1947; Twitchell 1951; Rondot 1969) and the cerebellum (Babinski 1902; Holmes 1917, 1939; Conrad and Brooks 1974; Soechting et al. 1976).

While there is considerable information with respect to disturbances of alternate motion rate in both hemiparetic and cerebellar patients, evidence about deficits occurring during rapid successive contractions which have to be performed isometrically, is still lacking. An isometric testing method would however allow assessment of the ability to perform rapid successive contractions even in patients suffering from grave motion deficits.

Clinically suitable equipment for the continuous registration of performance on motor tasks is not yet available. Unfortunately, most of the registration methods developed for animal research (e.g. Conrad and Brooks 1974) require too much preparation and are often too time consuming to be of any routine clinical use. The scope of this paper is to propose an economic method for the continuous registration of alternating force changes which allows investigation of distinctive features of succession deficits found in patients with lesions of the CNS. As an example of such an application, the present paper compares the performances of 10 cerebellar and 10 hemiparetic patients.

Methods

Apparatus. Details concerning the force measurement system used in the present study have been published elsewhere (Bolsinger and Mai 1985). Basically it consists of a modified Z80 based word processing system with added hardware for analog signal measurements, a commercially available high precision force transducer (Interface Inc., model SSM-AJ-200N), a specially designed amplifier and a suite of menu-driven interactive software. The equipment allows continuous registration of force over time. With a trial duration of 20 s, maximum sampling rate is 100 pps, giving 2,000 points. The amplifier supports force ranges of 5, 10, 25, 50, 100 and 250 N, the analog digital converter has a resolution of 256 steps.

In the present study, all measurements were done using the 25 N amplifier range, where amplitude resolution was approximately 0.1 N.

General Procedure. Subjects were seated in front of a 14″ graphics display which served for visual feedback. The transducer was held freely between thumb and index finger with all other fingers being maximally flexed (Bolsinger and Mai 1985). The subjects task was to produce fast repetitive force contractions and relaxations between two designated limits presented as horizontal lines on the display. The upper limit

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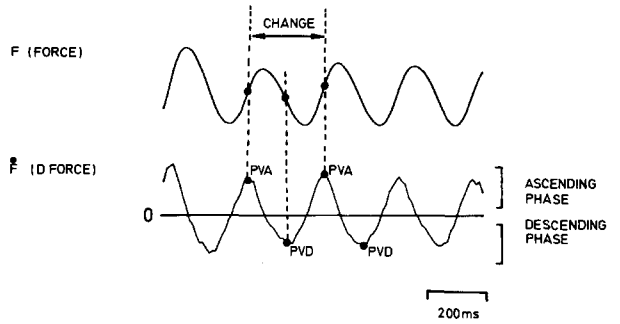

Fig. 1. Illustration of parameters. (FORCE): force-time curve; (D FORCE): force-velocity-time curve; CHANGE: complete force change; PVA: peak velocity during force ascending phase; PVD: peak velocity during force descending phase

was set to 18.75 N, the lower to 6.25 N. In addition, a vertical bar which varied continuously with forces exerted on the transducer was displayed on the screen. Subjects were instructed to produce forces greater than 18.75 N, and – during relaxation – smaller than 6.25 N. One trial lasted 20 s and instruction stressed maximal speed. The task was always introduced by having the subjects perform one or two practice trials, which were not saved for later data evaluation. All subjects had to perform this twice with both their left and right hands. Force time curves were stored on floppy disk. For each hand the best trial (with respect to the number of force changes) was selected for further data analysis.

Force Time Curve Parameters. Sampling time of force time curves was set to 10 ms, so that for each individual trial (lasting 20 s) 2000 data points were available. For each force time curve (F) the corresponding force velocity time curve (D FORCE) was computed. The following parameters (Fig. 1) were used as descriptions of subject performance:

- NFC, the total number of force changes performed in a trial
- MPVA, the arithmetic mean of all peak velocities PVA during the contraction or ascending phases of one trial
- MPVD, the arithmetic mean of all peak velocities PVD in relaxation or descending phases of one trial
- SI:=MPVA/MPVD, a symmetry index

Subjects. A total of 24 healthy right-handed subjects (12 females, 12 males) between 21 and 63 years of age served as normal controls. They received a small amount of money for their participation. The patients investigated were 10 patients with diffuse cerebellar disorders (C1...C10) and 10 patients suffering from hemiparesis (H1...H10). Focussing on the NFC variable, the selection of these subjects asked for gross and comparable deficits in both patients groups (Fig. 2). Moreover, all of them showed signs of grossly disturbed alternate motion as assessed by clinical testing.

Results

Normal Subjects

The means, SDs and ranges of the performance of the 24 healthy controls are summarized in Table 1 for all relevant parameters, namely NFC (in a trial of 20 s), MPVA, MPVD and SI. Only right hand trials

Table 1. Performance of 24 healthy persons.

	NFC	MPVA (N/s)	MPVD (N/s)	SI
Mean	78.33	375.33	368.46	1.04
SD	14.26	68.28	94.39	0.16
Range	56–102	251–534	207–511	0.76–1.36

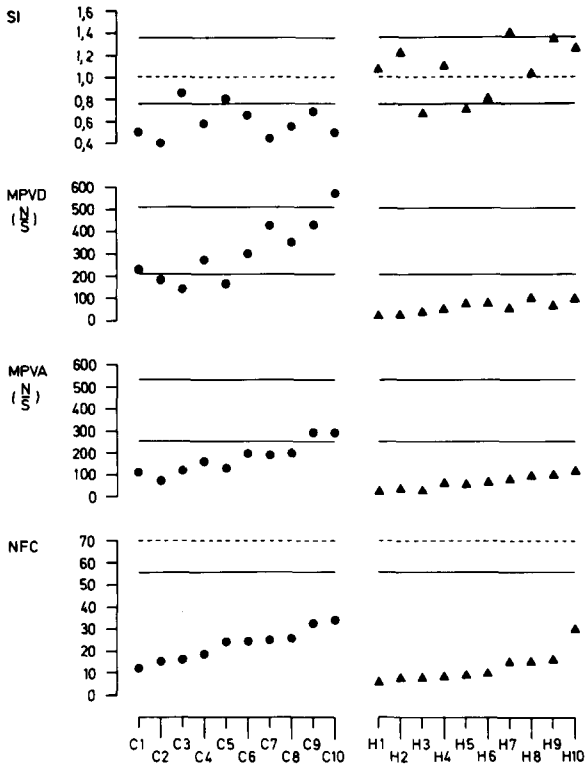

Fig. 2. Summary of results. C1...C10: cerebellar patients; H1...H10: hemiparetic patients; NFC: number of force changes per trial; MPVA: mean of peak velocities during force ascending phases; MPVD: mean of peak velocities during force descending phases; SI: symmetry index SI=MPVA/MPVD

are considered since results obtained for left hands did not alter normal ranges. Because performance variability was sometimes considerable (e.g. the summary statistics for the NFC variable, Table 1) we chose the very conservative criterion outside normal range for classification of pathological results.

Cerebellar and Hemiparetic Patients

Figure 2 provides a summary of the results obtained in the 10 cerebellar (C1...C10) and 10 hemiparetic patients (H1...H10). The patient numbers at the bottom of the Figure serve as references for all parameter diagrams. Horizontal lines respectively delineate the normal ranges for all parameters. All val-

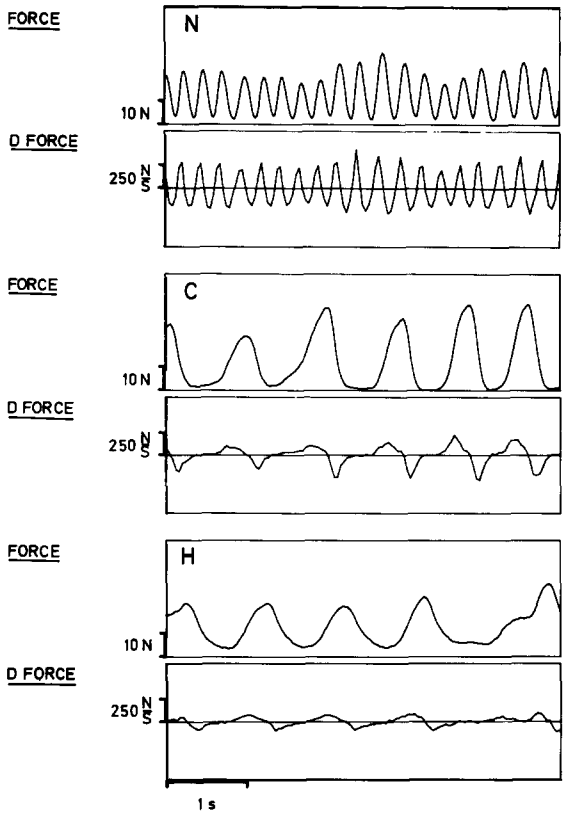

Fig. 3. Typical performance of a healthy person (N), a cerebellar patient (C) and an hemiparetic patient (H). Force time curves (FORCE) and force-velocity-time curves (D FORCE) are shown

ues refer to right hand trials, with the exeption of results obtained in H5, H6 and H10, who suffered from left-sided hemiparesis.

The results are reported separately for the different summary statistics, namely NFC, MPVA, MPVD and SI. In addition Fig. 3 shows typical force-time curves (FORCE) and force-velocity-time curves (D FORCE) of a healthy subject (N), a cerebellar patient (C) and an hemiparetic patient (H). Time intervals of 5 s are shown.

NFC (Number of Force Changes). As may be seen in Fig. 2 the NFC values were sorted in ascending order for each of the two patient groups. Filled circles (cerebellar patients) and triangles (hemiparetic patients) refer to the NFC values obtained during a trial of 20 s. Note that the normal range was limited to 70 force changes (dashed line), while the fastest control person reached 102 changes (Table 1). As a result of our patient selection procedure both groups showed strong and quite comparable deficits with respect to this parameter.

MPVA (Mean of Peak Velocities During Contraction Phases). This parameter was chosen to describe the force increasing phase. Again, both patient groups showed clear deficits. Mostly, the normal range was not attained so that peak velocities appeared to be too slow with respect to the performance of healthy persons. It should however be noted that 2 cerebellar patients (C9, C10) showed normal peak velocities in the force increasing phases whereas the same patients were clearly disturbed with respect to the NFC values obtained.

MPVD (Mean of Peak Velocities During Relaxation Phases). MPVD refers to the force decreasing phase. As could be expected from clinical experience the 10 hemiparetic patients (H1...H10) were invariably too slow in releasing force. As for the MPVA variable, results showed no considerable variability across patients. This was not true for the cerebellar patients (C1...C10) who seemed to represent a very heterogeneous group. Peak velocities ranged from below normal range (C2, C3, C5) to above normal range (C6). The main result is however summarized by the assertion that only 3 (C2, C3, C5) out of 10 cerebellar patients produced peak velocities too slow for the force relaxation phase. The other patients were able to generate a fast force release, while building up of force (see MPVA results) was often disturbed. Note that group separation was perfect for this parameter.

SI (Symmetry Index). The SI is defined by the ratio SI=MPVA/MPVD. It relates the peak velocities attained during the force increasing and decreasing phases. It was chosen as a simple description of given asymmetries in the building up and relaxation of force. With the exeption of H3, H5 and H7 who were slightly outside the normal range the hemiparetic patients showed no obvious differences between force ascending and force descending peak velocities. On the other hand most cerebellar patients were much faster in the force decreasing than in the force increasing phases. This was reflected by the SI values which were mostly below the normal range.

Discussion

By introducing a method for the assessment of the ability to perform fast repetitive force changes, we analysed some features of force-time curves which might throw light on different kinds of succession deficits in hemiparetic and cerebellar patients. It could be demonstrated that the frequence or rate of isometric force alternations (NFC) does not imply a specific force-velocity pattern.

The analysis of the performance of 10 cerebellar patients revealed considerable differences charac-

terizing the force increasing and decreasing phases. Most patients showed marked asymmetries with respect to peak velocities attained when increasing or decreasing force: though the majority of patients were able to release force as fast as normal controls, the same patients often had obvious difficulties in that the building up of force was characterized by a marked slowness. These results only partly confirm the work of Babinski (1902), Holmes (1917, 1939) or Conrad and Brooks (1974). According to Babinski (1902) and to Holmes (1917, 1939) the slowness in cerebellar succession deficits is due directly to a delay at the turn and not to the time lost in the movements themselves. Similarly, by studying the effects of dentate cooling on rapid alternating elbow flexions and extensions in three Rhesus monkeys, Conrad and Brooks (1974) found a decrease in the rate of alternations, whereas peak velocities and accelerations of these movements remained unaffected. Similar results have been reported by Soechting et al. (1976). In contrast to the highly unified picture of cerebellar disturbances provided by these authors, the types of deficits found in the present investigation showed considerable variability across patients, especially for the force decreasing phase (MPVD). A single cause for slowness, e.g. a delay at the turning points (Holmes 1917, 1939; Conrad and Brooks 1974) might indeed apply for the results obtained in patients C9 and C10: these patients produced high peak velocities in both the force ascending and descending phases. For all other patients however, additional problems resulted at least from the fact that the peak velocities attained during the force increasing phases were below the normal range. Patients C2, C3 and C4 even demonstrated slowness in both the force increasing and decreasing phases (see also Mai et al. 1988). A possible explanation for the obvious difficulties in building up force might result from the fact that our testing procedure asked for rapid isometric contractions which involved no digit movements. At least for simple movements (without any change of direction) Holmes (1939) stated that slowness becomes more obvious if the movement is performed against resistance.

Although both patient groups were quite comparable with respect to the NFC achieved per trial, a similar heterogeneity was not found in hemiparetic patients. The force-velocity parameters considered in the present study showed only little variation: all aspects of task performance (NFC, MPVA, MPVD) were grossly slowed down. Yet clinical research on hemiparetic syndromes (e.g. Walshe 1947; Twitchell 1951; Rondot 1969) has demonstrated that extension movements nearly always lag behind flexion movements in the recovery process, especially when finger dexterity is investigated. These findings lead to the expectation that hemiparetics should show a considerable asymmetry between force contraction and force relaxation phases, with a more marked slowness in the latter ones. This was not the case, as the SI index revealed. All patients showed gross and comparable deficits in both the force ascending and descending phases. The ability to produce repetitive muscle contractions and relaxations with great velocity is frequently believed to be fundamental for a great deal of motor skills such as writing, machine-operating or typing (e.g. Flowers 1976). In this sense, the absence of high peak velocities in the task performance of hemiparetic patients might be an explanation for the highly deteriorated dexterity of the hemiparetic hand.

The present results seem to qualify our method for the clinical investigation of neurologically impaired patients. It allows the assessment of residual hand functions even in hemiparetic patients suffering from excessive motion deficits and it obviously helps to differentiate between different functional deficits arising from lesions of the CNS. Moreover, the present procedure certainly provides a valuable tool for documenting and analysing the time course of neurological diseases. Finally, testing is non-invasive and it seldom takes more than a couple of minutes.

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