Scand J Rehab Med 2–3: 110–116, 1970

REFLEX FACILITATION BY MUSCLE VIBRATION IN THE TREATMENT OF SPASTIC HEMIPARESIS

E. Knutsson, U. Lindblom and I. Odéen

From the Departments of Clinical Physiology and Neurological Rehabilitation, Karolinska Sjukhuset, Stockholm, Sweden

ABSTRACT. As is well known, physiotherapy in combination with different types of reflex activation may be a valuable tool in the management of various neurological conditions involving pareses. Thus, vibration applied to a muscle or muscle group in order to elicit a tonic reflex contraction has recently been introduced as a therapeutic technique. This paper presents a critical evaluation of effects on paretic muscles achieved in 23 patients by vibratory treatment, as compared with effects produced in other paretic muscles when the patients were treated exclusively with conventional physiotherapy or received no treatment at all. Measurements of maximal voluntary contraction power and range of motion before and after a 3 week period of treatment revealed that the voluntary power increased slightly in some cases both in vibrated and non-vibrated muscles; this increase was however insignificant. The average range of motion increased slightly after vibratory treatment.

It is a widely accepted view that in various neurological conditions voluntary and/or static motor performances may be improved by physiotherapy in combination with reflex activation. For this purpose several methods have been developed (2, 7, 16) which are based upon the idea of inducing changes in the afferent discharge from proprioceptors and exteroceptors, thus facilitating motoneuron activation or reducing hypertonus.

The acute effects of changing the afferent impulse discharge can be striking but it is difficult to assess to what extent the reflex activation results in functional improvement outlasting the period of training. No comparative critical evaluation seems to have been made of the effects of physiotherapy with and without reflex facilitation, in spite of the fact that such studies are essential for the rational application of this type of therapy. The present paper describes an investigation in which the therapeutic results achieved in a number of patients by means of one specific form of reflex activation, viz. vibration of muscle, were compared with results obtained in the same patients by conventional physiotherapy alone.

It is well known that vibration applied to a particular muscle or muscle group produces a gradual involuntary contraction in the vibrated muscles and at the same time, although with a shorter latency, an inhibition of the antagonist (5, 8, 11, 19, 23). Results obtained in animal experiments (1, 3, 4, 10, 22) have provided evidence that these effects can be due to stimulation of group Ia afferents from the muscle spindles. Autogenic inhibition via Golgi tendon organs (cf. 21) and unknown effects of activation of other endorgans, expecially the highly vibration-sensitive Pacinian corpuscles (20) may play a role in determining the final plateau tension achieved in the vibrated muscles. The blocking effect on the typical tonic vibration reflex (TVR) by pharmacological agents influencing polysynaptic transmission as well as the absence of TVR below the level of spinal cord transection (8) indicate that the reflex pathway either transverses supraspinal centres or involves segmental internuncial pools under suprasegmental control. The gradual building-up of the reflex under constant stimulation and the post-stimulatory contraction (19, 21) point in the same direction.

Simultaneously with the tonic contraction there is a depression of the phasic stretch reflexes in the limb being vibrated. This has been proposed to be, at least in part, an occlusion phenomenon (11) but has also been shown to be dependent on a central mechanism (19, 23) which has been suggested to be presynaptic inhibition (9).

Vibration of muscle may have rather complex effects, but in many patients with central motor disorders it has been found to potentiate their voluntary contraction power (12, 13). Hagbarth & Eklund (13) studied the clinical applicability of TVR as a method of reflex stimulation that might be a useful adjunct in the management of central pareses. In the course of their investigation the question arose whether repeated vibration of muscle might have a cumulative effect resulting in long-term improvement of the voluntary power and range of motion. According to Hagbarth (personal communication, cf. also 6, 14) the effects of vibration are being tested in routine therapeutic work at various rehabilitation clinics, and many physiotherapists seem convinced that repeated sessions of vibration applied to weak muscle groups during attempts to perform movements may give long-term beneficial effects. No objective measurements of the degree of motor handicaps present before and after a period of treatment have however been carried out so far. In order to obtain reliable data in this respect we started, on the suggestion of Hagbarth and Eklund, a study of the effect of repeated muscle vibration using the stimulation technique developed by them. Our case material consisted of a number of patients with spastic hemiparesis whose motor performance proved to become potentiated in acute tests with muscle vibration and who might thus be expected to respond favourably to this therapy. For the selection of the material certain other criteria were also set up (cf. below) in order to ensure accurate and unequivocal results from comparisons between data from muscle groups treated with vibration and data from other muscle groups in the same patients treated with conventional physiotherapy alone.

MATERIAL AND METHODS

The initial material comprised a number of patients who according to hospital records or data obtained from their doctors had a severe hemiparesis but not a complete hemiplegia. Out of this primary material were first selected all patients whose disease was of more than a year's standing; this was considered adequate to rule out that any progressive spontaneous improvement or deterioration of the condition might interfere with the evaluation of the therapeutic results. After this elimination the number of cases was reduced to 140 patients who were either ambulatory or hospitalized at various clinics in Stockholm (47 cases from the Clinics of Neurology and Neurological Rehabilitation at Karolinska Sjukhuset, 42 cases from the Red Cross Hospital, 13 cases from the Rehabilitation Clinics of Danderyd's Hospital, 23 cases from Blackeberg's and Åkeshov's Hospitals for long-term care, and 15 cases from the Clinic of General Rehabilitation at the Southern Hospital). In most cases the cerebral lesion present was of vascular origin.

All these patients underwent a neurological examination, and the non-paralytic cases with marked paresis in the limb muscles were singled out. In these cases, comprising 50 patients, the acute effects of vibration applied to flexors and extensors of elbow and knee were studied using the type of vibratory stimulation extensively analysed in previous experiments on spastic muscle (12, 13). The vibrator was attached to the muscle tendon by a rubber band applied around the limb to be tested. The frequency of the vibratory stimulus was 150–160 Hz and the amplitude 1.0–1.5 mm depending on the tension of the rubber band and the softness of the underlying tissue.

In the group thus tested, 26 patients responded to the vibration by an increase in range of motion or strength of isometric contraction on maximal voluntary effort both in the upper and lower limb. These patients were selected for the investigation to be performed. However, three of them had to be excluded, one because of suicide, one because of relapse of her cerebrovascular disease, and the third because of onset of peripheral paresis in the affected arm. Thus, 23 cases remained for the final evaluation (12 men aged 34–81 years and 11 women aged 34–73). In 21 of these cases the hemiparesis present was due to cerebrovascular disease and in two to an extirpated cerebral tumour (meningioma). The vibratory as well as the conventional therapy was limited to flexors and extensors of elbow and knee on the affected side, and the patients were arbitrarily allotted to one of the following groups of treatment:

Group A. Arm treated with vibration, no treatment of the leg

Vibration was applied to the tendon of m. biceps or m. triceps for ten periods, each of 90 sec duration. In the course of the vibration, voluntary submaximal isometric contraction alternated with relaxation of the vibrated muscle. One minute's rest was allowed between each period of vibration. Each session thus took 25 min.

Group B. Arm treated with vibration and conventional training techniques, leg treated conventionally

The conventional exercise chosen consisted of repeated movements through the fullest possible range of motion against progressively increasing submaximal resistance (approx. 1/3–2/3 of maximal contraction force). The vibrator was applied as in Group A but was switched on for short periods (30 sec) during the resistive exercise to potentiate flexion (biceps vibration) or extension (triceps vibration) respectively. The arm was treated for 20 min, the leg for 10 min.

Group C. Arm trained with conventional techniques, leg treated with vibration

Vibration was applied to the patellar tendon or the tendons of the knee flexors during submaximal isometric contractions as in Group A. During the intervals of rest, extension and flexion of the elbow was trained with voluntary movements against progressively increasing submaximal resistance. Each session in this group took 30 min.

The patients were lying supine during the vibratory treatment as well as the conventional exercises. They all received one daily session 5 days per week (Monday through Friday) for 3 consecutive weeks. Voluntary arc of motion in the elbow and knee or voluntary power of the flexors and extensors were measured 3 to 5 days before and after the period of treatment. The contraction force was measured isometrically with a strain-gauge transducer or a cable-tensiometer. Both instruments recorded the tension of a band applied around the wrist of the hand or foot. The measurements were made during maximal voluntary effort for 3 to 6 sec and with the joint fixed at 90° except in a few cases in which limitation of the range of passive motion made it impossible; in these cases, one and the same angular position was used for the measurements before and after the period of treatment.

The variability of three consecutive measurements of the maximal voluntary force was ±20% except in one case in which a variation of up to 50% was observed. All comparisons of pre- and post-treatment values were based on the highest values found in each case. The voluntary arc of motion was measured with an angulometer. The accuracy of these measurements was ±5°.

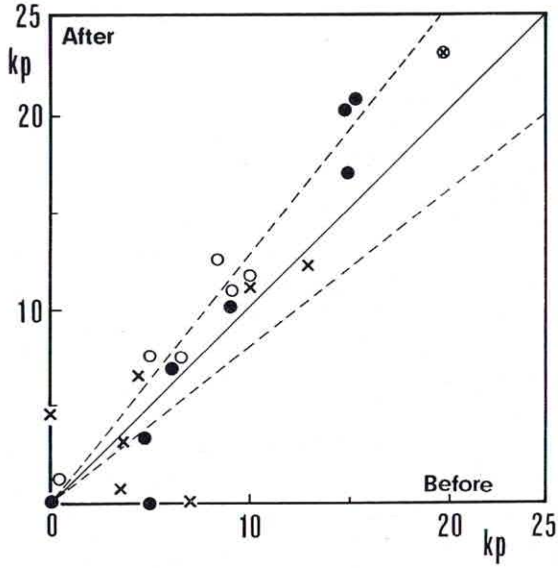

Fig. 1. Maximal voluntary contraction power of vibrated muscle groups before (*abscissa*) and after (*ordinate*) a 3 week period of treatment. Each symbol represents 1 patient and also indicates group of therapy, viz. ×, Group A (arm vibrated); ○, Group B (arm treated with vibration and conventional physiotherapy); ●, Group C (leg vibrated). Broken lines indicate variability of determinations in the single cases (±20%).

After the 3 week period of treatment, the patients were requested to give their subjective assessment of the effect of the vibratory therapy, and on the basis of their replies a classification was made according to a five-point scale as follows: 1, marked deterioration; 2, slight deterioration; 3, no effect; 4, slight improvement, and 5, marked improvement. Reports were obtained from 22 patients. A similar evaluation of the therapeutic effects was made by the physiotherapist.

In 13 cases a movie camera was used to illustrate movements chosen so as to show crucial points in the motor disturbances before and after the period of treatment.

RESULTS

Fig. 1 shows the maximal voluntary contraction force of the muscle groups treated with vibration before (abscissa) and after (ordinate) the period

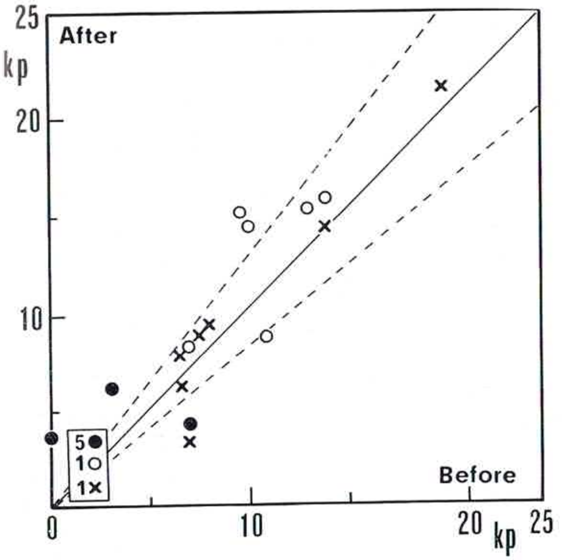

Fig. 2. Maximal voluntary contraction power of antagonists of the vibrated muscle groups of Fig. 1 before (*abscissa*) and after (*ordinate*) the 3 week period of treatment. Symbols as in Fig. 1.

of treatment. Each symbol represents 1 patient and also indicates the group of therapy to which he had been allotted. The variability of the determinations, $\pm 20\%$, is indicated by the broken lines. Twelve symbols are comprised within these lines, thus showing that in these cases no significant change in contraction force could be observed. In 7 cases there was an increase in power exceeding 20%, in 4 cases a decrease exceeding this limit. As appears from the figure, the overall result was a slight average increase in muscular power, which was also confirmed by the numerical calculations which gave a mean increase of 0.53 ± 2.30 kp (mean, S.D.; $n = 23$). This increase is however insignificant.

Since the acute effect of vibration, apart from an increase in the voluntary power of the vibrated muscles, usually is an inhibition of their antagonists, repeated vibratory treatment might result in maintained inhibition of these muscles. Hence, we also measured the maximum voluntary contraction force of the antagonists before and after the period of treatment. The values thus obtained are plotted in Fig. 2, from which it appears that the result is similar to that obtained for the vibrated muscles. In 3 cases the power was reduced but in 4 cases it was increased. The overall result was an insignificant increase in power, amounting to 0.63 ± 2.00 kp ($n = 23$). In 7 cases the power was too small to be measurable (less than 0.2 kp) both before and after the treatment, as indicated at origo.

Fig. 3 illustrates the maximal voluntary contraction force in the non-vibrated limbs before and after the period of treatment. Values from both flexors and extensors (44 muscle groups altogether) are included in the figure, in which filled circles represent Group C (arms treated conventionally), open circles Group B (legs treated conventionally) and crosses Group A (untreated legs). As seen in the figure, there is in most cases no significant change, neither in the limbs treated conventionally (●, ○) nor in the untreated extremities (×). Seven muscle groups, one of them untreated, displayed an increase in power exceeding 20% and 5 cases a decrease exceeding this limit. The latter cases include two muscle groups in which the power decreased below measurable val-

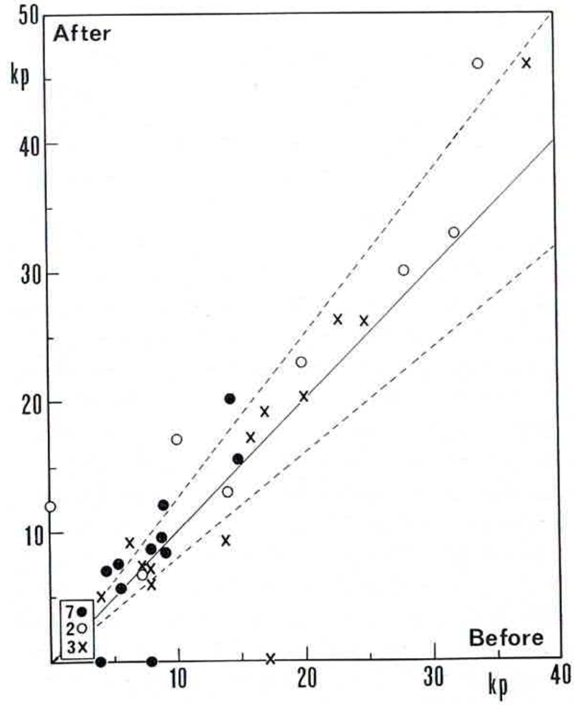

Fig. 3. Maximal voluntary contraction power of non-vibrated muscle groups (flexors and extensors) treated conventionally or untreated, before (*abscissa*) and after (*ordinate*) the 3 week period. Each symbol represents one muscle group. ×, Group A (untreated legs); ○, Group B (legs treated conventionally); ●, Group C (arms treated conventionally). Broken lines indicate variability of determinations as in previous figures.

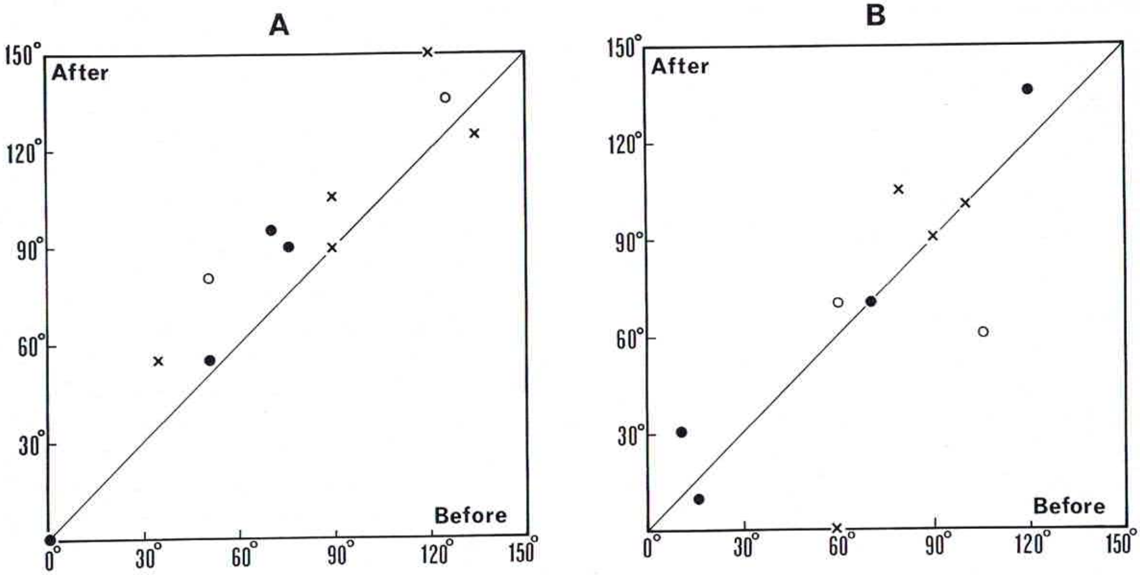

Fig. 4. Range of voluntary motion before (*abscissae*) and after (*ordinates*) the 3 week period of treatment. *A*, vibrated muscle groups; *B*, non-vibrated muscle groups. Symbols as in previous figures.

ues in spite of the treatment (● on abscissa). The muscle groups treated conventionally exhibited an average increase in power of 1.11 ± 4.84 kp ($n = 29$), whereas in the case of the untreated muscles there was an average increase of 0.98 ± 3.88 kp ($n = 15$).

The values of the voluntary power in non-vibrated extremities were more dispersed than those of the vibrated limbs. However, the relation between the maximal strength of muscle groups on the affected side and of corresponding muscles on the contralateral side, viz. roughly the degree of paresis, was almost the same for the vibrated (40%) and the non-vibrated (39%) muscle groups.

The results thus achieved in the present investigation do not suggest that the average maximal voluntary contraction force should have been significantly altered in any of the four series of muscle groups studied, viz. those treated with vibration, their antagonists, and muscles treated conventionally or untreated. Nor is there any significant difference between these four groups.

In some cases an encouraging improvement in voluntary force could be observed. Most remarkable was the result achieved in one patient in whom a muscle group with no measurable pre-treatment power developed a power of 12 kp after a 3 week period of conventional physiotherapy (○ on ordinate, Fig. 3).

In the group treated with vibration, the range of voluntary motion was limited in 11 patients because of a relatively severe paresis. In the group of patients not treated with vibration such a limitation was present in 10 cases. The effects achieved by the therapy applied in the different cases are illustrated in Fig. 4, in which *A* shows the range of motion of the vibrated muscle groups before and after the treatment, and *B* the same values for the non-vibrated muscle groups serving as control. After the period of treatment, the range had increased in 7 cases treated with vibration, the average increase being 12° (S.D. = 13, $n = 11$). This increase is significant with a high degree of probability. In the group of non-vibrated muscles, the range of voluntary motion increased only in 4 patients; in 2 cases a reduction occurred. The

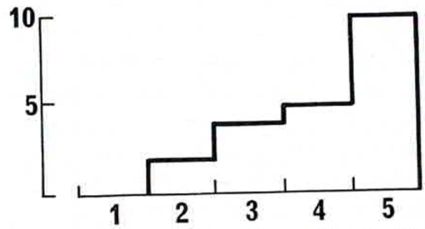

Fig. 5. Histogram illustrating patients' subjective estimates of effects of vibration after the 3 week period of treatment. *1*, marked deterioration; *2*, slight deterioration; *3*, no effect; *4*, slight improvement; *5*, marked improvement. *Ordinate:* number of patients.

average change in the non-vibrated extremities was insignificant (−4°).

The possibility had to be taken into account that the treatment might have induced changes in the motor patterns that were not revealed by our measurements of voluntary power or range of motion. But inspection of the film data obtained in the case of 13 patients before and after the period of treatment did not reveal any changes in the motor patterns apart from those which could be deduced from the measurements performed.

Even though the recorded increases in voluntary power were relatively small and infrequent, most patients noted a subjective improvement of their motor functions in the extremities treated with vibration. This is dramatically illustrated in Fig. 5, showing their own ratings of the effects according to the five-point scale mentioned above. As seen, there is a general tendency toward a positive assessment of the therapeutic effects and no less than 10 patients reported marked improvement. Further, the physiotherapist was of the opinion that the motor performance of the vibrated limbs had improved in most of the patients.

DISCUSSION

In this investigation no long-term improvement of the maximal voluntary contraction power of paretic muscles was achieved by reflex facilitation induced by the muscle vibration technique employed. The insignificant increase in strength of the vibrated muscle groups resulting in some cases did not exceed the increase observed in muscle groups that had been treated with conventional therapeutic exercises or had received no treatment at all. With respect to range of motion, however, the increases noted in limbs treated with vibration differ from the insignificant changes in the corresponding control group.

Even though the actual increase in voluntary power was insignificant, the subjective effect, as experienced by most of the patients and as reported by the physiotherapist, was a marked improvement. It should be borne in mind that the objective measurements reveal only the momentary contraction effects and do not allow a complete quantitative evaluation of the motor handicap present. The good subjective results might have been a consequence of improved functions not measured in this study, e.g. endurance and coordination, or of reduced hypertonus. It is not likely, however, that the spasticity present should have been markedly diminished since such a reduction usually enhances the contraction power of the antagonists of the spastic muscles and thus should have been apparent as an increase of the maximal voluntary power measured. Thus, for instance, depression of the stretch reflex by local muscle cooling (15, 18) highly increases the contraction power of the antagonists (17). Hence, if the repeated vibration should have significantly and lastingly reduced the hypertonus present, this should have been revealed by the measuring technique used. The possibility that the coordination might have been improved was also taken into consideration, but the films of patients photographed when performing various test movements before and after the treatment did not reveal any discernible changes apart from those which could be ascribed to the observed changes in voluntary power or range of motion. The way in which the patients experienced the vibration therapy suggests that the inevitable placebo effects may be pronounced. This may, at least in part, explain the difference between the objective measurements and the subjective assessments.

Thus, reflex facilitations induced by the muscle vibration technique employed in this study does not regularly result in long-term functional improvements. This may be due to the fact that vibration activates several types of receptors and that the effect produced by the sensory inflow from these different receptors may vary with the type and degree of lesion in the central nervous system. Furthermore, the vibratory stimulus may have not only facilitatory but also inhibitory effects. In our material such inhibitory effects may have been predominant in the cases in which the voluntary power decreased after the treatment. Similar effects may also, in the other cases, have counteracted facilitatory effects. It is also possible that a long term effect requires much longer facilitation periods or even structural changes in the cerebro-spinal system.

Of the 26 patients responding favourably to the acute tests, 23 could receive the 3 week period of treatment. Significant increases in voluntary power or range of motion were about twice as common in the groups treated with vibration (Figs. 1 and 4 *A*) as in the control groups (Figs. 3 and 4 *B*). These effects are too infrequent and of too slight functional importance to warrant recommendation of muscle vibration as a standard type of therapy in spastic pareses, but of course the results obtained in this study do not generally rule out this treatment as a physiotherapeutic tool. Unfortunately, the patients responding satisfactorily to vibration did not exhibit any special characteristics which would enable selection of those most likely to profit by this therapy. Our material consisted of patients with stationary lesions of cerebrovascular origin. In cases with recent lesions more satisfactory results may be achieved, although the therapeutic effects will be difficult to evaluate because of concomitant spontaneous regression. It is also conceivable that patients with other types of motor disturbances may respond more satisfactorily to vibration. Thus, for instance, very encouraging observations have been reported from screening tests performed on children with cerebral palsy (6). It will be of interest to get further information about those results as well as the outcome of the other investigations of vibration effects in routine therapeutic work now in progress at various rehabilitation clinics. Comparisons between results obtained by muscle vibration, on the one hand, and by other methods used to facilitate activation of paretic muscles, on the other hand, should also be of interest, since the data so far available are not sufficient for a critical assessment of the relative advantages of the different techniques.

ACKNOWLEDGEMENTS

This investigation was supported by the Swedish Multiple Sclerosis Foundation, the Folksam Rehabilitation Board, and the Swedish Medical Research Council, Stockholm.

REFERENCES

1. Bianconi, R. & Van der Meulen, J. P.: The response to vibration of the end organs of mammalian muscle spindles. J Neurophysiol *26:* 177, 1963.
2. Bobath, K.: The neuropathology of cerebral palsy and its importance in treatment and diagnosis. Cereb Palsy Bull *8:* 13, 1959.
3. Brown, M. C., Engberg, I. & Matthews, P. B. C.: The relative sensitivity to vibration of muscle receptors of the cat. J Physiol (London) *192:* 773, 1967.
4. Echlin, F. & Fessard, A.: Synchronized impulse discharges from receptors in the deep tissues in response to a vibrating stimulus. J Physiol (London) *93:* 312, 1938.
5. Eklund, G. & Hagbarth, K.-E.: Normal variability of tonic vibration reflexes in man. Exp Neurol *16:* 80, 1966.
6. Eklund, G. & Steen, M.: Muscle vibration therapy in children with cerebral palsy. Scand J Rehab Med *1:* 35, 1969.
7. Fay, T.: Basic considerations regarding neuromuscular and reflex therapy. Spastic Quarterly *3:* 5, 1954.
8. de Gail, P., Lance, J. W. & Neilson, P. D.: Differential effects on tonic and phasic reflex mechanisms produced by vibration of muscles in man. J Neurol Neurosurg Psychiat *29:* 1, 1966.
9. Gillies, J. D. & Lance, J. W.: Presynaptic inhibition of the monosynaptic reflex by vibration. J Physiol (London) *205:* 329, 1969.
10. Granit, R. & Henatsch, H. D.: Gamma control of dynamic properties of muscle spindles. J Neurophysiol *19:* 356, 1956.
11. Hagbarth, K.-E. & Eklund, G.: Motor effects of vibratory muscle stimuli in man. *In* Muscular Afferents and Motor Control. Nobel Symposium 1 (ed. R. Granit), pp. 177–186. Almqvist & Wiksell, Stockholm, 1966.
12. — Tonic vibration reflexes (TVR) in spasticity. Brain Res *2:* 201, 1966.
13. — The effects of muscle vibration in spasticity, rigidity and cerebellar disorders. J Neurol Neurosurg Psychiat *31:* 207, 1968.
14. — The muscle vibrator—a useful tool in neurological therapeutic work. Scand J Rehab Med *1:* 26, 1969.
15. Hartviksen, K.: Ice therapy in spasticity. Acta Neurol Scand, Suppl *3, 38:* 79, 1962.
16. Kabat, H.: The role of central facilitation in restoration of motor function in paralysis. Arch Phys Med *33:* 521, 1952.
17. Knutsson, E.: On effects of local cooling upon motor functions in spastic paresis. Progr Phys Med *1:* 126, 1970.
18. Knutsson, E. & Mattsson, E.: Effects of local cooling on monosynaptic reflexes in man. Scand J Rehab Med *1:* 126, 1969.
19. Lance, J. W., de Gail, P. & Neilson, P. D.: Tonic and phasic spinal cord mechanisms in man. J Neurol Neurosurg Psychiat *29:* 535, 1966.
20. Lindblom, U. & Lund, L.: The discharge from vibration-sensitive receptors in the monkey foot. Exp Neurol *15:* 401, 1966.
21. Marsden, C. D., Meadows, J. C. & Hodgson, H. J. F.: Observations on the reflex response to muscle vibration in man and its voluntary control. Brain *92:* 829, 1969.
22. Matthews, P. B. C.: The reflex excitation of the soleus muscle of the decerebrate cat caused by vibration applied to its tendon. J Physiol (London) *184:* 450, 1966.
23. Rushworth, G. & Young, R. R.: The effect of vibration on tonic and phasic reflexes in man. J Physiol (London) *185:* 63, 1966.

Address for reprints:
Ulf Linblom, M.D.
Head of the Department of Neurological Rehabilitation
Karolinska Sjukhuset
104 01 *Stockholm,* Sweden

Key-words: Reflex Facilitation, Muscle Vibration, Treatment of Spastic Hemiparesis