THE "VIBRATOR" — THERAPEUTIC TOOL OR ACADEMIC TOY?

K. E. BRINKWORTH, B.Sc. (Physio.) (Witwatersrand)

Mechanical vibration of skeletal muscle has been a subject of interest in the field of neurophysiological research for some years. The reflex contraction of muscle tissue when subject to mechanical vibration of certain frequencies was demonstrated electromyographically by Hagbarth and Eklund in 1966 **(1)**. The term given to this response is the TONIC VIBRATORY REFLEX and considerable research has been done over the last ten years investigating the nature of this reflex and its clinical application for both therapeutic and diagnostic purposes **(2, 3)**. Whereas the physiological reports have been vast and interesting, the clinical use and specific practical application for physiotherapists has not so far been adequately investigated. Therefore it was felt that a review of the literature to date and a report on recent investigation into some aspects of the practical application of the Tonic Vibratory Reflex would be of some value to the physiotherapist.

Subsequent to the first observations of the effects of vibration on muscle tissue, numerous studies have been done using various frequencies of vibration and noting effects such as the chances in phasic and tonic reflex mechanisms **(4)**, the nature of the H-response and tendon reflexes **(5)** and the type of tension or tone built up in the muscle tissue **(6, 7)**. The effect of vibration has been compared with that of electrical stimulation of muscle afferents **(7)** and factors which increase or decrease the tonic vibratory reflex have been investigated. Studies have been conducted on decerebrate cats, on healthy human subjects and on patients with central nervous system lesions. In all, there is a wealth of basic research on the subject which is now slowly being taken up by physiotherapists, but considering the wealth of material which has been offered the clinician, it is amazing to find apparently only one independent report submitted by a physiotherapist so far. This consisted of some case reports done by Stillman in Australia in 1970 **(8)**.

Let us consider then the facts which emerge having sifted through this material and selected that which is of obvious practical clinical relevance.

FREQUENCY OF STIMULUS

Matthews (1966) showed that the muscle tension produced is directly proportional to the frequency of stimulation **(13)**. Various frequencies of vibration have been used experimentally, however it seems that frequencies ranging from 50 to 500 Hertz are those which have been most used in human skeletal muscle. For clinical purposes Hagbarth and Eklund in Sweden used vibrators oscillating at 150 Hz **(9)**, while Stillman conducted his clinical studies using 50 Hz **(8)**. Both are undoubtedly effective and the type of vibrator commercially available in this country has a frequency of 100 Hz.

It is interesting to note that in recent studies at the University of the Witwatersrand the cylindrical battery-operated vibrator showed a tremendous range of frequencies with basically two components of 330 and 660 Hz emerging **(10)**. This vibrator has proved relatively less effective than others of lower frequency. It has been suggested that with higher frequencies there is a loss of effective energy and probably decreased amplitude by the time the stimulus reaches the muscle tissue **(12)**.

Bishop (1975) considers a frequency of 200 Hz should be the upper limit of a clinical vibrator **(11)**.

SITE OF APPLICATION OF STIMULUS

In laboratory preparations where the vibratory stimulus could be applied directly to muscle tissue, the effect of the stimulus was the same for any fibre or group of fibres. However, in the clinical situation the effectiveness of the stimulus will naturally vary with the site of application, the condition of stretch and the initial tone of the muscle. The accessibility of the muscle is also an important consideration. All skeletal muscle will respond to vibration but all skeletal muscles are naturally not selectively accessible. Most workers have found that the muscle tendon is the most effective site of stimulation, with Stillman reporting that in the case of gastrocnemius, a point proximal to the musculo-tendonous junction produces the most effective response **(8)**.

Thus while the muscle tendon can be taken generally as the most suitable site of application in the clinical situation, it is suggested that the therapist apply the vibratory stimulus first over the muscle tendon, then having allowed a reasonable time for a response to take place (two minutes), and failing to get a response, to then repeat the stimulus over the musculo-tendonous junction and over muscle fibres proximal to this point **(12)**.

TIME OF APPLICATION OF STIMULUS

The tendency is to withdraw the stimulus if a dramatic response is not immediately perceptible. Although this is not advisable, Bishop (1975) does point out that after two minutes the stimulus should be withdrawn due to the heat of friction on the skin. It must be borne in mind, however, that a stimulus frequency of 100-200 Hz was being referred to in this instance and that lower frequencies might well not have this effect so soon, as borne out by Marsden et al (1969) who used a frequency of 100 Hz and reported no ill-effects when this was applied for periods of up to twenty minutes **(7)**.

While electromyographically, a response to vibration can be picked up on immediate onset of stimulus, this is not always immediately perceptible using other methods of recording such as degree of joint movement or the response of a pressure transducer. However, "plateau tension" was reached in gastrocnemius studies within 30 to 60 seconds **(7)** and responses in quadriceps femoris using joint movement as an indication of response, have been observed in periods of up to two minutes **(12)**.

Another interesting point should be noted in the clinical situation and that is the phenomenon described as Post-Vibratory Potentiation. This means that "a previous period of vibration will potentiate a response to a subsequent period of vibration" (Marsden et al 1969). The interval between periods of vibration in which this took place was five seconds to three minutes. Potentiation always disappeared after a five minute interval. Therefore the therapist could be advised to repeat vibratory stimulation after rest periods of less than three minutes.

AMPLITUDE OF STIMULUS

Matthews (1966) has shown how the tension of the tonic vibratory reflex is increased with increased amplitude (up to 200 u) at a constant frequency of 300 Hz. Note that increased amplitude will cause increased recruitment of motor units and that in therapeutic situations this is sometimes but not always the desired effect. In fact, judicious use of amplitude must be employed to avoid the production of a tonic vibratory response in muscle tissue where a response is not required. A good example here is the phenomenon observed when treating the hand where the finger flexors respond when the muscles of the thenar eminence are being vibrated. This has particularly been observed where amplitudes of more than 2 millimetres are used with a frequency of 50 Hz **(12)**.

The amplitudes used clinically are not always specifically stated in the literature, however it seems wise to keep below 2,5 mms due to the above effect and only to resort to the larger amplitudes when an increase of frequency of up to 200 Hz does not produce a response.

FACTORS AFFECTING THE TONIC VIBRATORY RESPONSE

In the normal subject the tonic vibratory reflex can be increased or decreased in intensity in certain circumstances. Drugs such as valium, barbiturates, Ciba 28,882-Ba and prociane block will depress the response **(4, 8)** and normal subjects can voluntarily depress the response. Vibration of the agonist will decrease the response to vibration of the antagonist muscle. This ties up reasonably with the fact that vibration of a skeletal muscle will not only result in a sustained contraction of the muscle vibrated, but also in a simultaneous relaxation of its prime antagonist **(17)**.

The position of the head has also been found to influence the effect of vibration with flexors responding better in prone and the extensors in supine, thus demonstrating a link-up with the mechanisms of the tonic labyrinthine reflex **(1)**.

There is no correlation between the strength of the tendon jerks in any individual and the strength of the tonic vibratory response **(15)**, however a Jendrassik-like like response is observed in which the tonic vibratory response is increased when the subject contracts other muscle groups **(4, 6)**. It has been observed too that cold increases this response. The initial muscle length has an influence whereby a greater response is recorded when a muscle is vibrated while in its outer range **(11)**; this fact will hold as long as the tone of the muscle is the same in both positions, but with increased tone, there will similarly be an increased response to the vibratory stimulus.

OTHER NEUROPHYSIOLOGICAL FINDINGS

Having established the fact that the tonic vibratory reflex is the tonic reflex contraction of skeletal muscle when subject to high frequency mechanical vibration and that reflex inhibition of the antagonist takes place simultaneously (Yamanaka 1964, Hagbarth and Eklund 1966, Matthews 1966 and De Gail et al 1966), it is interesting to consider some other effects which have been observed in nerve and muscle tissue when vibration is taking place.

Muscle Receptors

It has been graphically shown how the primary endings from the muscle spindle can be seen to discharge at the same frequency as the vibratory stimulus whereas the secondary endings and the Golgi tendon organs are relatively unresponsive **(14)**. However, the Golgi tendon organs, while having a high threshold to stretch have a low threshold to contraction and these fibres could start responding to some degree as the tension plateau is reached or as an overall response takes place in the muscle.

The "H" Response and Tendon Jerks

The H response (also called the H reflex) can be considered the electrical equivalent of the ankle jerk **(4)**. It is elicited by stimulating the afferent axons with an electric shock (thus by-passing the spindles), a reflex muscle contraction ensues. Both the H response and the tendon jerks were found to be depressed during vibration. This is thought to be due to pre-synaptic inhibition. These phasic reflexes are depressed during vibration whether the spinal cord is intact or not, whereas the tonic vibratory reflex is absent in decerebrate cats and in patients with cervical and thoracic spinal cord lesions **(4, 5, 13)**. This implies that the tonic vibratory reflex depends on long reflex pathways involving higher centres, whereas the depression of the phasic reflexes depends on spinal cord circuits **(5)**. Arcangel, Johnston and Bishop (1970) found that although phasic reflexes were depressed during vibration, the Achilles' tendon reflex was augmented for some 30 seconds after vibration of the tendo-achilles.

This, to a degree, ties up with Marsden, Meadows and Hodgson's observations in 1969 on post-vibratory potentiation and Brown, Engberg and Matthews' observations on the initial muscle tension and fusimotor activity with reference to relative sensitivity to muscle vibration **(14)**. Bishop describes this as a gamma-generated augmentation brought about during vibration and persisting afterwards while the alpha motor neurons are still subject to presynaptic inhibition.

CLINICAL APPLICATIONS — IN SUMMARY

The use of the tonic vibratory reflex in early diagnosis of neurological pathology and in investigating the physiological functioning of human muscle spindles has been put forward by many workers in this field, Hagbarth and Eklund (1966) and Marsden et al (1969) being two examples **(7, 16)**. Hammond, Merton and Sutton (1956) remarked that the tendon jerk is probably no more than "an accidental overload condition of a nervous pathway" with Marsden et al subsequently stating in 1969 that "the physiological and pathological functioning of human muscle spindles is more likely to be discovered by the use of techniques such as vibration than by the use of the tendon hammer".

So much for the changing face of diagnosis and research, but what of the therapist? In summary, the items of practical and therapeutic use which emerge from this wealth of research are put forward.

Mechanical vibration of frequencies ranging from 50 to 200 Hz is best used in the therapeutic situation. Vibrators operating at 50 Hz thus *oscillating* at 100 Hz are readily commercially available in this country. The amplititude of vibration is probably most effective for selective amplication of small muscles when less than 2,5 mm. Amplitude may be increased with no reported ill-effects, bearing in mind that more motor units and thereby possibly other muscles will be affected.

The time for vibration over any one point should probably not exceed two minutes if frequencies approaching 200 Hz are used. With lower frequencies the application could be re-applied after rest periods of less than three minutes. Further investigation is required here to assess effects at different frequencies. The best site for application of the stimulus in the clinical situation appears to be over the muscle tendon although a response can be elicited over the musculo-tendonous junction or over the muscle belly. This variation in optimal site of stimulation could depend on the initial muscle length or the state of contraction or tone of the muscle at the onset of vibration.

So far vibration therapy has been most reported in the treatment of patients with upper motor neurone lesions with some reference to the effect it might have on weak or paresed muscle tissue. (By virtue of the fact that vibration results in contraction of the fibres vibrated with inhibition of the antagonist, it is reported to reinforce weak voluntary efforts and to reduce spasticity when applied to the antagonist of the spastic muscle.) However, far more clinical assessment is called for in this field and this can only be done with a more judicious and specific application of the vibratory stimulus and an awareness of the physiological data concerned with the evolution of this technique.

REFERENCES

1. Hagbarth, K.-E. and Eklund, G.: "Normal variability of tonic vibration reflexes in man." Exp. Neurol. 16:80-92. Sept. 1966.
2. Hagbarth, K.-E. and Eklund, G.: "The effects of muscle vibration in spasticity, rigidity and cerebellar disorders." J. Neurol. Neurosurg. Psychiat. 31:207-213. June 1968.
3. Stockmeyer, S. A.: "An Interpretation of Rood in the treatment of neuromuscular dysfunction." Amer. J. Phys. Med. 46:900-956. 1967.
4. De Gail, P., Lance, J. W. and Neilson, P. D.: "Differential effects on tonic and phasic reflex mechanisms produced by vibration of muscles in man." J. Neurol. Nuerosurg. Psychiat. 29: I-II. 1966.
5. Arcangel, C.S., Johnston, R. and Bishop, B.: "The Achilles Tendon Reflex and H-Response during and after tendon vibration." Physical Therapy 51:8 889-901. 1971.
6. Johnston, R. M., Bishop, B. and Coffey, G. H.: "Mechanical Vibration of Skeletal Muscles." Physical Therapy 50:4 499-505. April 1970.
7. Marsden, C. D., Meadows, J. C. and Hodgson, H. J. F.: "Observations of the Reflex Response to Muscle Vibration in Man and its Voluntary Control." Brain 92: 829-846. 1969.
8. Stillman, B. C.: "Vibratory Motor Stimulation — a Preliminary Report." Australian J. Physiotherapy XVI: 3 118-123. Sept. 1970.

9. Eklund, G.: "Some physical properties of muscle vibrators used to elicit tonic proprioceptive reflexes in man." Acta. Soc. Med. Uppsala. 76: 271-280. 1971.
10. Brinkworth, K. E. and Schuster, D. G.: "Studies of Physical Properties of Vibrators." Unpublished. 1974.
11. Bishop, B.: "Vibratory Stimulation — Part III — Possible Applications of Vibration in the treatment of Motor Dysfunctions." Physical Therapy 55: 2 139-143. Feb. 1975.
12. Brinkworth, K. E.: "Further Studies on the Clinical Application of the Tonic Vibratory Reflex." Unpublished. 1975.
13. Matthews, P. B. C.: "The reflex excitation of the soleus muscle of the decerebrate cat caused by vibration applied to its tendon." J. Physiol. 192: 773-800, 1967. 184: 450-472. 1966.
14. Brown, M. C., Engberg, I. and Matthews, P. B. C.: "The relative sensitivity to vibration of muscle receptors of the cat." J. Physiol. 192: 773-800. 1967.
15. Hagbarth, K.-E. and Eklund, G.: "The muscle vibrator — a useful tool in neurological therapeutic work." Scand. J. Rehab. Med. I: 26-34. 1969.
16. Hagbarth, K.-E. and Eklund, G.: "Tonic Vibratory Reflexes in Spasticity Brain Research 2: 209-203. 1966.

OPSOMMING

Die ontwikkeling van die tonies-vibrerende-refleks as 'n diagnostiese en 'n terapeutiese hulpmiddel word bespreek. Die tonies-vibrerende-refleks word gedifinieer as die toniese refleks-sametrekking van skeletspier wanneer dit onderworpe is aan hoë frikwensie meganiese vibrasie met refleksinhibisie van die antagonis. Hierdie refleks is in die laboratoriumsituasie vir die laaste tien jaar ondersoek en die kliniese toepassing word nou voorgestel. Die tyd van toepassing, vibreringswydte en frikwensie wat as die geskikste vir kliniese gebruik beskou word, word bespreek. Ander aanverwante neurofisiologiese aspekte van die tonies-vibrerende-refleks word beskryf ten opsigte van hulle verband met die kliniese situasie. Die tonies-vibrerende-refleks word as 'n nuttige hulpmiddel in fisieketerapeutiese werk beskou, met besondere toepassing in die neurologiese veld. Fisioterapeute moet die basiese beginsels van hierdie tegniek verstaan om dit met maksimale voordeel in kliniese praktyk toe te pas.