Reprinted from the Archives of Neurology
April 1975, Volume 32

Human Masseter Muscle: H- and Tendon Reflexes

Their Paradoxical Potentiation by Muscle Vibration

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We developed a method for direct electrical stimulation of the masseter nerve in man. Both direct M-responses and genuine H-reflexes were recorded from the ipsilateral masseter muscle. Muscle vibration that inhibits the Achilles tendon reflex and the soleus H-reflex was found to potentiate the masseter tendon reflex and also the masseter H-reflex. This unexpected contrast may be related to peculiar brain stem circuitry of the masseter reflex mechanism.

(*Arch Neurol* 32:229-234, 1975)

The masticatory motor system and particularly the myotatic reflexes of the masseter muscle have been little investigated in man,[1,2] in spite of their interesting features disclosed in several studies on the cat.[3-5] The primary I_A afferent fibers from the masseter spindles have their cells of origin in the mesencephalic V nucleus and form monosynaptic excitatory synapses on the homonymous masseter motoneurons.[6,7] In contrast to the reciprocal reflex organization at spinal cord level, the cat's masseter I_A axons do not exert any direct inhibitory effects on the antagonistic motoneurons of the jaw-opening muscles.[5] The jaw openers apparently do not contain any muscle spindles in the cat[8] nor in man,[9] which suggests that the masseter motoneurons would not be submitted to any reciprocal inhibitory effect of proprioceptive origin.

We believe this communication on neurophysiological features of the masseter reflexes in man describes for the first time a masseter H-reflex evoked by the electrical stimulation of the spindle afferents in the masseter nerve. H-reflexes have been primarily investigated in the human triceps surae muscle,[10-12] and offer a useful tool in studies of motor system disorders.[13] The disclosure of a masseter H-reflex provides unusual opportunities for testing current views based on H-reflex studies on the lower limb. For example, the pathophysiological discussions of the inhibition of triceps surae reflexes by muscle vibration[14-19] obviously must be reassessed, in view of the present findings that the masseter H-reflex is unexpectedly not reduced by muscle vibration.

Accepted for publication July 31, 1974.

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MATERIALS AND METHODS

Seventeen normal unpaid volunteers of either sex, between 22 and 29 years old, were studied. They were all free of any symptom or sign of neurological disease. Subjects received no sedation nor any drug. They were all physically fit and they had given informed consent for the procedures, which they subsequently described as mild and quite acceptable. The application of vibration to the chin was considered unpleasant to some extent, especially for certain vibration frequencies (about 80/sec), which were avoided.

The subjects were seated in an easy chair with their head resting against a sturdy metal frame padded with soft rubber. Two elastic bands strapped one each around the forehead and the mandible (between the chin and lower lip) prevented any movement of the head in the receptacle. The lower elastic band also served to secure a compact DC motor equipped with an eccentric load on its axis against the midline mandible, in order to provide a vibratory stimulus at about 100/sec with an amplitude of 1.5 mm. The tendon reflexes were elicited at five-second intervals by an electromechanical-hammer rigidly fixed in front of the head frame.

The device was carefully adjusted for orientation and distance, in order to deliver an adequate blow to the vibrator fixed to the chin. The impact of the hammer was not changed when the vibrator was ener-

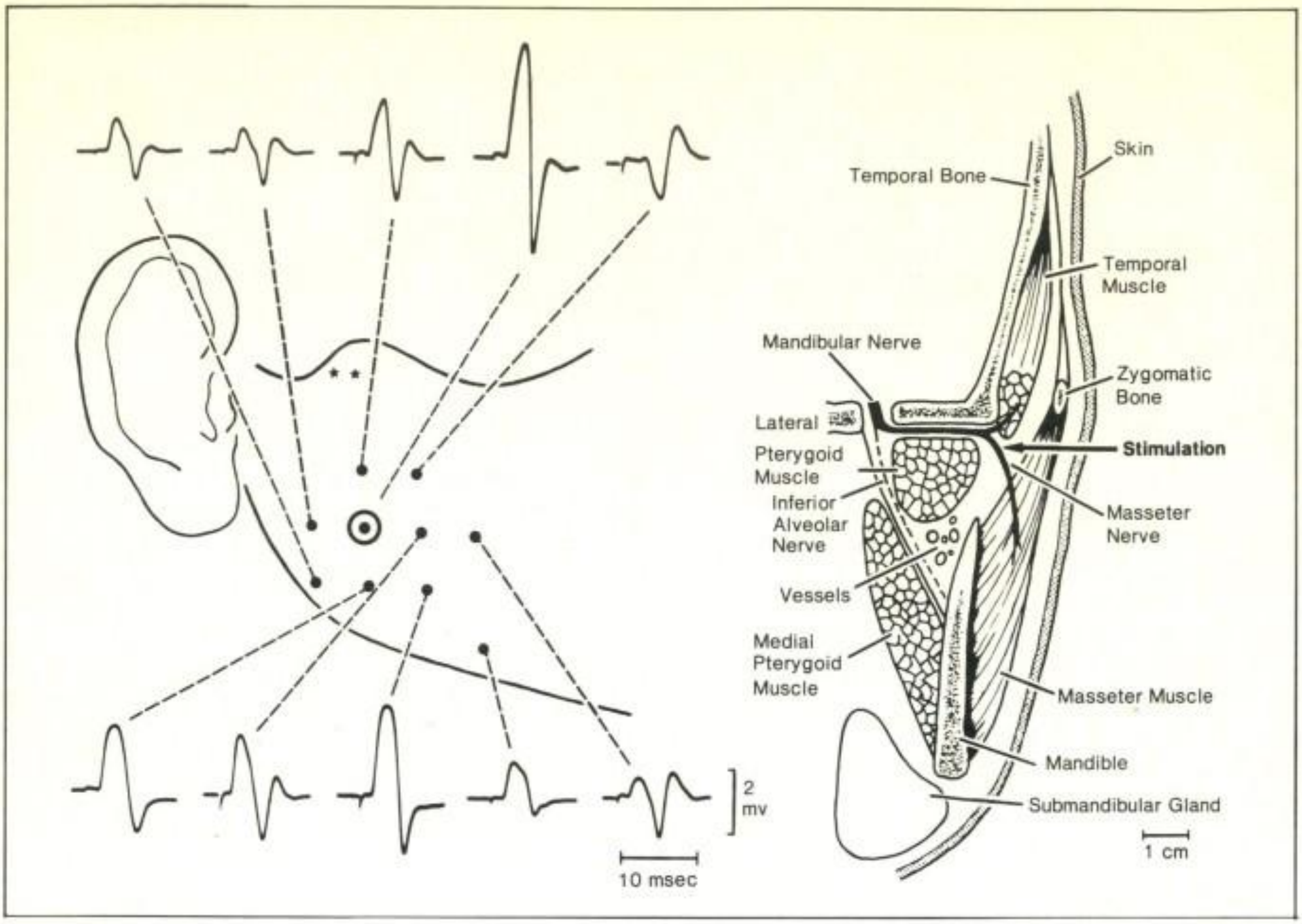

Fig 1—Electrical stimulation of masseter nerve. Left, Topography of belly-tendon electrical responses of masseter muscle to single supramaximal stimulus. Position of each active recording electrode on the lateral aspect of lower face, below zygomatic bone (dots). Masseter motor point (circled dot). Reference electrode is in neck. Negativity of active electrode records upward. Position of stimulating electrodes (stars). Right, Frontal transection of human head in plane of masseter nerve.

gized in order to study the influence of vibration on tendon reflexes. Under our experimental conditions, the mechanical impact of the hammer was consistently reproducible, since the latency between the trigger pulse and the tendon reflex potential was fairly stable, with or without vibration.

The Achilles tendon reflex was studied with the same arrangement, the subject being seated with the foot strapped on a standard footplate. The knee was semiflexed at 120°, and the ankle joint had an angle of 100°.[20] The plunger of the solenoid device also made its impact on the vibrator, which was strapped to the Achilles tendon about 3 cm above the calcaneus.

The masseter H-reflex was evoked by a square electrical pulse of 1 msec duration delivered to the masseter nerve. Preliminary dissections of two cadaver heads fixed in formaldehyde solution, one of which transected in the appropriate frontal plane (Fig 1, right) provided the required anatomical landmarks. The steel needles used for stimulation were insulated with Teflon except for the 1.5-mm tip, and their outside diameter was 0.5 mm. Two such needles sterilized by boiling for 15 minutes were inserted 5 mm apart to a depth of 20 mm, perpendicular to the skin and slightly below the zygomatic bone (Fig 1, left, [stars]). The use of Teflon insulation prevented spread of the stimulating currents and minimized artifacts even for supramaximal intensities (Fig 1, left). The frontal section (Fig 1, right) shows that the needles in the recommended position do not approach the internal maxillary artery and the pterygoid venous plexus, which are situated mediocaudally to the masseter nerve. Electrical stimuli were not repeated at intervals below 5 sec, and their intensity was monitored by a 1111_A current probe.

The belly-tendon responses of the masseter muscle were picked up by fine subcutaneous steel needles[21] or by silver cups placed on the skin. The reference electrode was located below the angle of the mandible. The subject was grounded by a subcutaneously placed unshielded steel needle that was inserted slightly below the stimulating electrodes. The position of the ground was less critical when recording the masseter tendon reflex. The muscle potentials were amplified by a homemade, 10 meg ohms-input impedance preamplifier and displayed on a cathode-ray oscilloscope. The traces were photographed. The 35-mm films were measured after enlargement. Similar studies of the H-reflex of the triceps surae muscle were carried out by stimulating the tibial nerve in the popliteal fossa with the Simon electrode,[20] and by recording the electrical response with bipolar skin electrodes placed 3 cm apart over the soleus muscle.

RESULTS

Masseter M- and H-Responses

The optimal electrode positions for recording the belly-tendon electrogram of the masseter muscle were studied during supramaximal stimula-

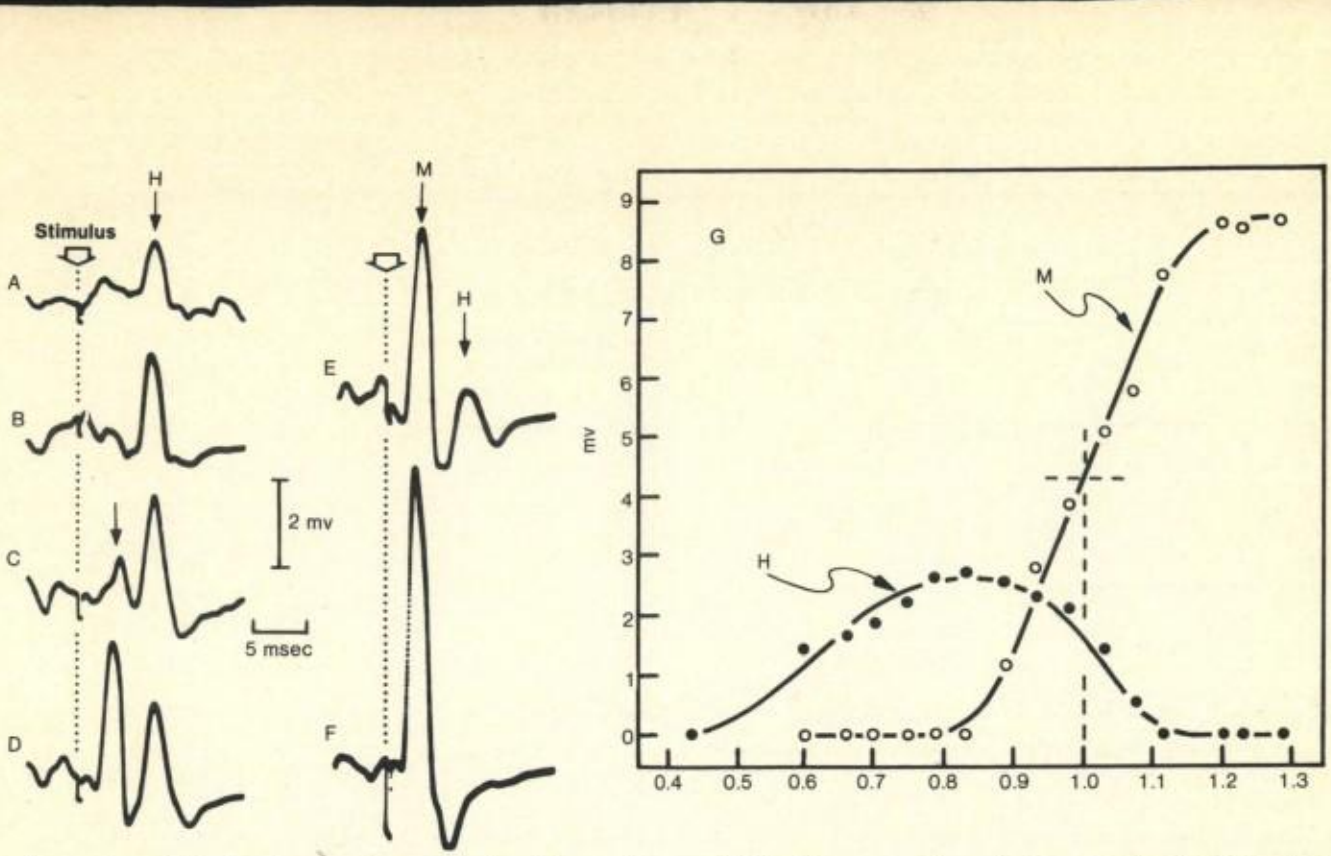

Fig 2.—Normal H-reflex in masseter muscle of a 22-year-old man. A to F, Oscilloscope records of belly-tendon electrical responses for electrical stimulation of masseter nerve with pulse of 1.0 (A), 1.2 (B), 1.4 (D), 1.5 (E), and 3.7 ma (F). Direct M- and H-reflex components are indicated. G, Voltage in mv of M (circles) and H (dots) components as function of intensity of electrical stimulus in same experiment. Reference value for relative intensity on abscissa corresponds to intensity eliciting M response, 50% of maximum value. Each symbol in the diagram represents mean amplitude of ten successive responses.

tion of the masseter nerve ((Fig 1, left). Responses of maximum voltage, starting with a negative component, were recorded at about the lower third of the muscle, which corresponds to its motor point tested by standard electrodiagnosis, as shown for other muscles.[21] The direct masseter M-responses to a supramaximal nerve stimulus had a mean peak-to-peak voltage of 7.3 mv (range, 5.0 to 10.6 mv), their negative component had a mean duration of 2.7 msec (range, 2.4 to 3.0 msec). The onset latency varied from 1.3 to 1.9 msec in the different normal adult subjects tested. In subjects with the masseter muscle normally relaxed, no H-reflexes were recorded. For supramaximal intensities, however, the M-response was sometimes followed by a small component of about 5.8 msec peak latency that presumably corresponded to the F-wave[22] as it persisted at still higher intensities. By contrast, a masseter H-reflex was readily recorded when the subject voluntarily kept his jaw tightly closed. Under such conditions, the stimulation elicited at first only a "late" response of about 7.0 msec peak latency (Fig 2, A). As the stimulation intensity was progressively increased, this late response augmented while the direct M- response appeared (Fig 2, C). With stronger stimuli, the M-response progressively increased while the late response decreased and eventually disappeared altogether (Fig 2, E and F). Under our conditions, the stimulus intensities eliciting a maximum late response was about 1.5 ma. The sequence is similar to the classical lower limb H-reflex,[10-12] as is the diagram plotting masseter H- and M- responses as a function of relative stimulus intensity (Fig 2, G). The mean voltage of the maximum masseter H-reflex was 1.9 mv, with a range of 0.75 to 4mv. This corresponded to a mean of 24% (range, 11% to 37%) of the maximum direct M-response in the same subject. These relative amplitudes of the masseter H-reflex were still below the range of 35% to 75% described for the normal soleus H-reflex when this is tested without voluntary contraction of the muscle.[12] The onset latency of masseter H-reflex ranged from 4.6 msec to 5.8 msec, with a mean of 5.4 msec. In a given subject, the onset latency and its variability are smaller for masseter H-reflex (4.6 msec; SD, 0.22 msec) than for masseter tendon reflex (7.5 msec; SD, 0.43 msec).

When stimulating the masseter nerve to elicit an ipsilateral H-reflex, no similar reflex responses could be recorded either in the contralateral masseter muscle or in the ipsilateral temporal muscle. The masseter H-reflex is thus confined to the muscle whose nerve is stimulated.

Muscle Vibration on Tendon Reflexes

When vibration is applied to a limb, the tendon jerks are reduced or abolished.[14-16] This classical effect (Fig 3, A and B) for the Achilles reflex was not recorded for the masseter tendon reflex, which was, on the contrary, definitely potentiated by jaw vibration (Fig 3, C and D). This difference between the two muscles was consistently found in the 12 normal subjects tested, with a mean potentiation of + 30% in the masseter reflex and a mean reduction of −73% in the Achilles reflex (Fig 4).

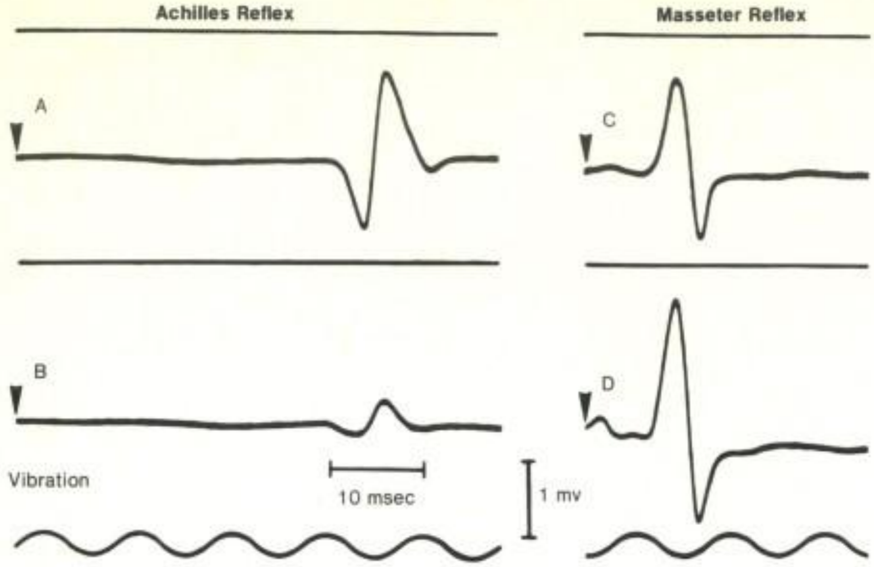

Fig 3.—Effect of muscle vibration on tendon reflexes elicited by percussion (arrows) of Achilles tendon (A, B) or of mandible (C, D). Vibration at 100/sec applied in B and D.

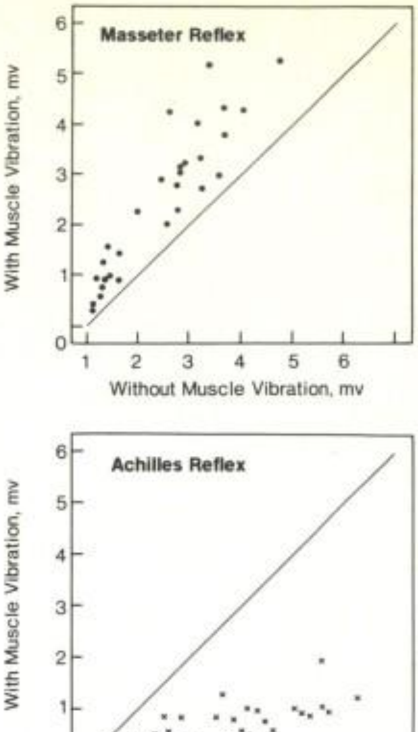

Fig 4.—Pooled results on 12 normal subjects relating voltage of tendon reflexes elicited by percussion. With or without muscle vibration. The 45° line would correspond to lack of any effect of vibration. Top, Potentiation of masseter reflex by vibration. Bottom, Inhibition of Achilles reflex by vibration. Each symbol corresponds to mean voltage of ten successive reflexes elicited at 5-sec intervals.

The relative changes were roughly similar for reflexes over a size range from 0.1 mv to several millivolts. In our experiments, the vibrations were applied for 2 minutes, while the tendon reflexes were elicited every five seconds. The vibration-induced depression of the Achilles reflex appeared rapidly and reached its maximum a few seconds after the vibration had been started.[18,24] The masseter reflex potentiation appeared in the first few seconds of vibration, it remained at the same level throughout, and persisted for about five seconds after discontinuation of the jaw vibration. No masseter reflex depression was noticed subsequently, when the vibration potentiation had dissipated.

Muscle Vibration on H-Reflex

The H-reflex of the triceps surae muscle is inhibited by vibration of the Achilles tendon[14-18] and the effect has also been recorded for the H-reflex evoked during voluntary plantar flexion of the foot[18] (Fig 5, B and D). Thus, the reflex potentiation associated with voluntary activation of the prevent the demonstration of the vibration-induced depression of phasic reflexes. The masseter H-reflex was always elicited during voluntary closure of the jaw; however, in this muscle, the vibration applied to the chin elicited no depression, but only a slight potentiation (Fig 5, A and C). It is not surprising that the masseter H-reflex was only slightly potentiated by vibration, since the reflex was already facilitated by the voluntary contraction in our experimental conditions.

When assessing our results with vibration, it must be stressed that similar effects were recorded for the masseter H-reflex and for the masseter tendon reflex, the latter being tested without any voluntary closure of the mouth. The contrast between vibration depression of the Achilles jerk and the vibration potentiation of the masseter tendon reflex was observed consistently (Fig 3 and 4) in the relaxed muscles tested under identical experimental conditions.

Comment

The method described for electrical stimulation of the masseter nerve proved safe and reliable. With due precautions, the needle electrodes do not interfere with the big vessels and other structures at the base of the skull. Supramaximal electrical stimuli were well tolerated by the subjects, and they elicited M belly-tendon electrical responses of 5 to 10, 6 mv peak-to-peak amplitude in the masseter muscle (Fig 1). This method extends nerve stimulation procedures to the masseter muscle and also allows the demonstration of genuine H-reflexes involving the brain stem in man. The usual criteria for the H-reflex[10-12] were fulfilled in this method, since the late component was evoked below the threshold of the direct M component, and since its amplitude decreased when the M component augmented with stronger stimuli to the nerve (Fig 2).

The recruitment curves for the M- and H-responses had a pattern similar to the classical one in the triceps surae muscle. It should be pointed out that the masseter H-reflex was observed consistently when the reflex was facilitated by voluntary closure of the jaw. The maximum amplitude of the reflex averaged about 24% of the maximum M-response in the same subject. The latency of the masseter H-reflex was

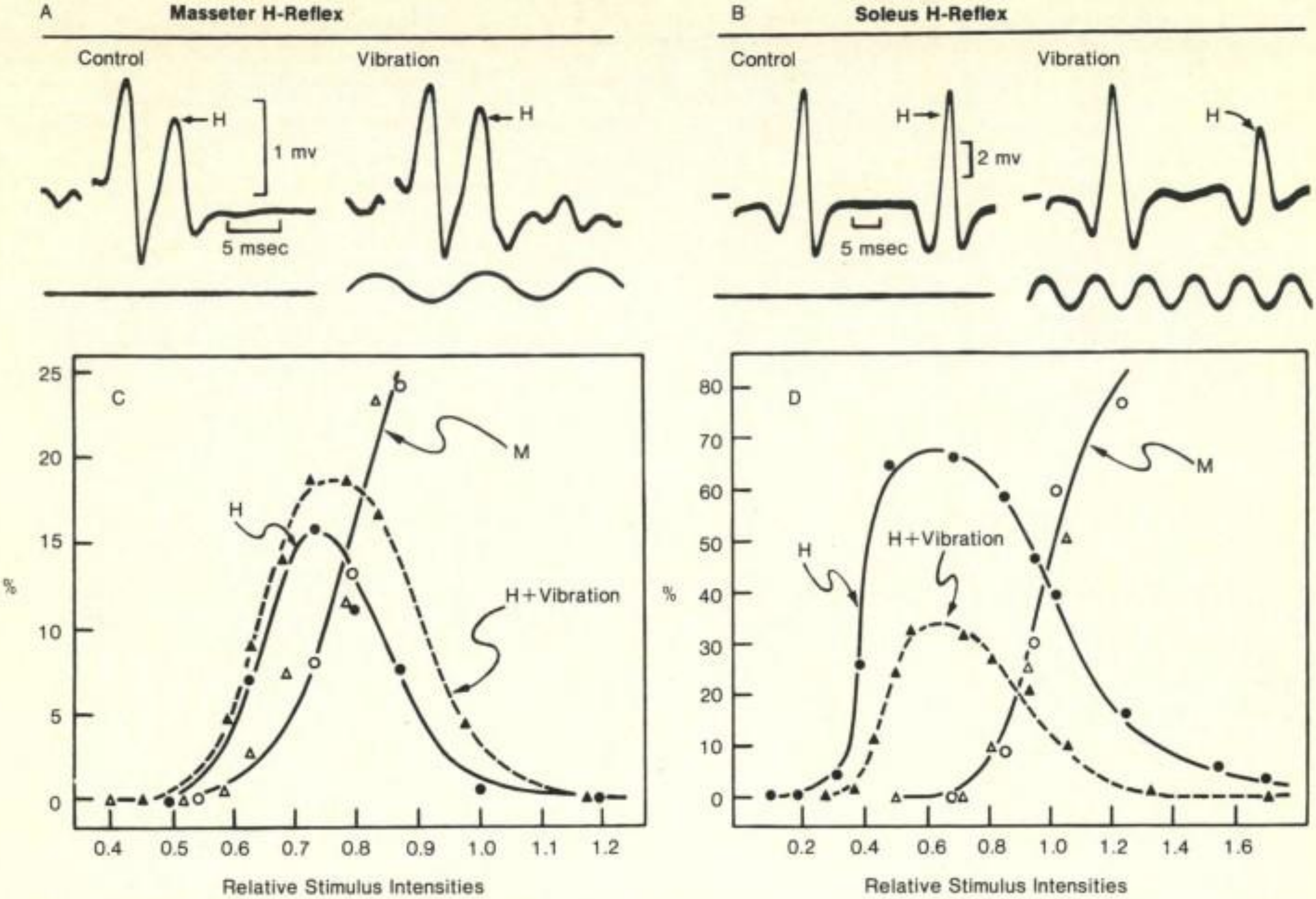

Fig 5.—H-reflex in masseter (A, C) and soleus (B, D) muscles. A and B, H-reflexes preceded by direct M response, with and without vibration. C and D, Recruitment curves of M and H components in percent of maximum M response. Relative stimulus intensities, reference value corresponding to intensity eliciting an M response, 50% of maximum value. Interrupted curves correspond to H-reflexes elicited during vibration (filled triangles). H-reflexes without vibration, (dots). M responses without vibration (circles) and M responses with vibrations (open triangles).

quite stable in each subject, and the small standard deviation of 0.22 msec is compatible with a monosynaptic pathway.

One of our main findings is that jaw vibration failed to depress the masseter tendon (Fig 3 and 4) or H-reflexes (Fig 5), in striking contrast to the inhibition recorded with the same experimental conditions for the triceps surae tendon (Fig 3 through 5) or H-reflexes. This is important in view of the pathophysiological significance attached to the muscle vibration studies in motor disorders[19,23,25]

The functional organization of the masseter reflexes presents unique features, among which the virtual lack of proprioceptive spindle input from the antagonistic jaw-opening muscles[9] are particularly relevant for this discussion. Vibration is a powerful stimulus for spindle primary endings,[26,27] and the proprioceptive afferents activated by jaw vibration will be essentially those of the jaw-closing muscles. The observation of a facilitation of the masseter T- and H-reflexes during vibration would thus indicate that autogenetic inhibitory mechanisms from spindle afferents are of little, if any, significance in the vibration-induced changes.

The evidence presented in this communication, having taken advantage of the special circuitry of a brain stem reflex pathway, makes it necessary to reconsider the well known depression of triceps surae H- and T-reflexes by vibration of the Achilles tendon. In the latter case, the vibration must spread to antagonistic muscles and even to more distant muscles, all of which do possess muscle spindles. Application of the vibrator to ankle or knee flexors and indeed anywhere in the leg also elicits a depression of the triceps surae phasic reflexes.[16,18] In animal experiments, the vibration-induced depression of soleus reflexes appeared related to presynaptic inhibition of the spindle afferents of the triceps by the primary spindle afferents originating from knee-flexor muscles.[28-30]

The unexpected contrast found between triceps surae and masseter reflexes with respect to vibration effects could be simply explained if the main part of the vibration-induced presynaptic inhibition resulted from activation of primary spindle afferents in antagonistic or distant muscles (triceps surae), an effect that cannot be present in the case of the masseter. The problems thus raised are outside the scope of this communication, but they make it clear that studies of H-reflexes in different muscles, and particularly in the masseter with its peculiar brain stem circuitry, considerably extend the scope of studies of motor mechanisms in man.

This research has been supported by the Fonds de la Recherche Scientifique Médicale, the Fonds National de la Recherche Scientifique, from which Dr. Godaux is holding a postdoctoral research fellowship, and the Muscular Dystrophy Associations of America, Inc.

Jaques Mulnard, MD (Department of Anatomy) provided the anatomical material.

References

1. Mc Intyre AK, Robinson RG: Pathway for the jaw-jerk in man. *Brain* 82:468-474, 1959.

2. Goodwill CJ, O'Tuama L: The normal jaw reflex: Measurement of the action potential in the masseter muscles. *Ann Phys Med* 9:183-188, 1968.

3. Hugelin A, Dumont S: Inhibition réticulaire du réflexe d'ouverture de la gueule. *Arch Ital Biol* 99:219-243, 1961.

4. Emmelin N, Zotterman Y (eds): *Oral Physiology*. New York, Pergamon Press Inc, 1973.

5. Kidokoro Y, Kubota K, Shuto S, et al: Reflex organization of cat masticatory muscles. *J Neurophysiol* 31:695-708, 1968.

6. Szentàgothai J: Anatomical considerations of monosynaptic reflex arcs. *J Neurophysiol* 11:445-454, 1948.

7. Hugelin A, Bonvallet M. Etude électrophysiologique d'un réflex monosynaptique trigéminal. *C R Soc Biol* 150:2067-2071, 1956.

8. Szentàgothai J: Functional representation in the motor trigeminal nucleus *J Comp Neurol* 90:111-120, 1949.

9. Voss H: Zahl und Anordnung der Muskelspindeln in den oberen Zungenbeinmuskeln, im M. trapezius und M. latissimus dorsi. *Anat Anz* 103:443-446, 1956.

10. Hoffman P:*Untersuchungen über die Eigenreflexe (Sehnenreflexe) menschlicher Muskeln*. Berlin, Springer-Verlag, 1922.

11. Paillard J:*Réflexes et Régulations D'origine Proprioceptive Chez L'homme. Étude Neurophysiologique et Neuropsychologique*. Paris, Arnette, 1955.

12. Hugon M: Methodology of the Hoffmann reflex in man, in Desmedt JE (ed): *New Developments in Electromyography and Clinical Neurophysiology*. Basel, S Karger, 1973, vol 3.

13. Desmedt JE (ed): *New Developments in Electromyography and Clinical Neurophysiology*, vol 3. Basel, S Karger, 1973.

14. Eklund G, Hagbarth KE: Motor effects of vibratory muscle stimuli in man. *Electroencephalogr Clin Neurophysiol* 19:619P, 1965.

15. De Gail P, Lance JW, Neilson PD: Differential effects on tonic and phasic reflex mechanisms produced by vibration of muscles in man. *J Neurol Neurosurg Psychiatr* 29:1-11, 1966.

16. Rushworth G, Young RR: The effect of vibration on tonic and phasic reflexes in man. *J Physiol* 185:63-64, 1966.

17. Marsden CD, Meadows JC, Hodgson HJ: Observations on the reflex response to muscle vibration and its voluntary control. *Brain* 92:829-846, 1969.

18. Delwaide PJ: *Étude expérimentale de l'hyperréflexie tendineuse en clinique neurologique*. Bruxelles, Arscia, 1971.

19. Burke D, Ashby P: Are spinal "presynaptic" inhibitory mechanisms suppressed in spasticity? *J Neurol Sci* 15:321-326, 1972.

20. A discussion of the methodology of the triceps surae T- and H-reflexes, in Desmedt JE (ed): *New Developments in Electromyography and Clinical Neurophysiology*, vol 3. Basel, S Karger, 1973, pp 773-780.

21. Desmedt JE: Méthodes d'étude de la fonction neuromusculaire chez l'homme: Myogramme isométrique, électromyogramme d'excitation et topographie de l'innervation terminale. *Acta Neurol Belg* 58:977-1017, 1958.

22. Mayer RF, Feldman RG: Observation on the nature of the F-wave in man. *Neurology* 17:147-156, 1967.

23. Lance JW, de Gail P, Neilson PD: Tonic and phasic spinal cord mechanisms in man. *J Neurol Neurosurg Psychiatr* 29:535-544, 1966.

24. Lance JW, Burke D. Andrews CJ: The reflex effects of muscle vibration, in Desmedt JE (ed): *New Developments in Electromyography and Clinical Neurophysiology* vol 3. Basel, S Karger, 1973, pp 444-462.

25. Delwaide PJ: Human monosynaptic reflexes and presynaptic inhibition, in Desmedt JE (ed): *New Developments in Electromyography and Clinical Neurophysiology*, vol 3. Basel, S Karger, 1973, pp 508-522.

26. Matthews PBC: The advances of the last decade of animal experimentation upon muscle spindles, in Desmedt JE (ed): *New Developments in Electromyography and Clinical Neurophysiology*, vol 3. Basel, S Karger, 1973, pp 95-125.

27. Hagbarth KE: The effect of muscle vibration in normal man and in patients with motor disorders, in Desmedt JE (ed): *New Developments in Electromyography and Clinical Neurophysiology*, vol 3. Basel, S Karger, 1973, pp 428-443.

28. Gillies JD, Lance JW, Neilson PD, et al: Presynaptic inhibition of the monosynaptic reflex by vibration. *J Physiol* 205:329-339; 1969.

29. Barnes CD, Pompeiano O: Presynaptic inhibition of extensor monosynaptic reflex by IA afferents from flexors. *Brain Res* 18:380-383, 1970.

30. Barnes CD, Pompeiano O: Effects of muscle vibration on the pre- and postsynaptic components of the extensor monosynaptic reflex. *Brain Res* 18:384-388, 1970.

Printed and Published in the United States of America