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Research Note

The Effects of Muscle Vibration on the Attainment of Intended Final Position During Voluntary Human Arm Movements*

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Summary. Muscle tendon vibration was applied during voluntary step-tracking arm target-movements performed by normal human subjects. Vibration (freq. = 120 Hz) was applied over either the biceps or triceps tendons. During non-visually guided (eyes closed) trials, vibration of the muscle antagonistic to the movement being performed resulted in an undershoot of the required target. Thus, biceps vibration produced an undershoot of the extension target and triceps vibration an undershoot of the flexion target. The same effect occurred if the vibration was applied continuously over several movements or only during the course of individual movements. In contrast, vibration of the muscle acting as the prime mover had no effect on the correct attainment of the required target. It is suggested that the central nervous system may monitor muscle afferent activity of the lengthening (antagonist) muscle during simple, step movements.

Key words: Vibration – Voluntary movement

Utilizing muscle tendon vibration, Goodwin and his colleagues demonstrated a systematic distortion of the perception of elbow joint position when one of the muscles at that joint was vibrated (Goodwin et al. 1972). For instances, when the vibrator was applied over the biceps tendon, the forearm was always perceived to be more extended than it actually was. Such a finding was consistent with the activation of length-sensitive receptors such as muscle spindles. In the present study, high frequency muscle vibration was used to activate muscle spindle afferents during voluntary target-directed human arm movements. The question was asked whether such afferent proprioceptive information generated *during* movement could affect the subsequent course of the movement. If this were the case it seemed likely that attainment of intended final limb position would be affected by vibration in a way consistent with activation of muscle spindles.

A total of 15 subjects have now been investigated. During experiments the subjects were seated in a chair and grasped a manipulandum handle, their forearm being supported just distal to the elbow. The handle was pivoted at one end and could be moved in the horizontal plane by flexion or extension movements about the elbow. A precision potentiometer mounted at the axis of rotation was used to monitor handle, and thus forearm, position. Angular velocity of handle movement was measured using a small DC torque motor.

Subjects performed step-tracking movements following a target displayed as a vertical bar on a cathode ray tube placed in their line of sight, 1 m in front of them. The target switched every 3 s between two fixed positions. Target positions were not bounded by mechanical stops. Subjects were instructed to move "briskly and accurately" to the new target position following target switch. The handle position was displayed on the CRT as a thin vertical line. In some experiments the subjects were required to perform the task without visual guidance, i.e. with their eyes closed, target movement being signalled by an auditory cue. In these experiments no external cues were given to signal attainment of the required target. All subjects were well practiced at the task and could attain the required targets equally well with or without visual guidance.

A small vibrator was securely fastened over the biceps or triceps tendon using adjustable Velcro straps. The vibrator consisted of a small DC motor

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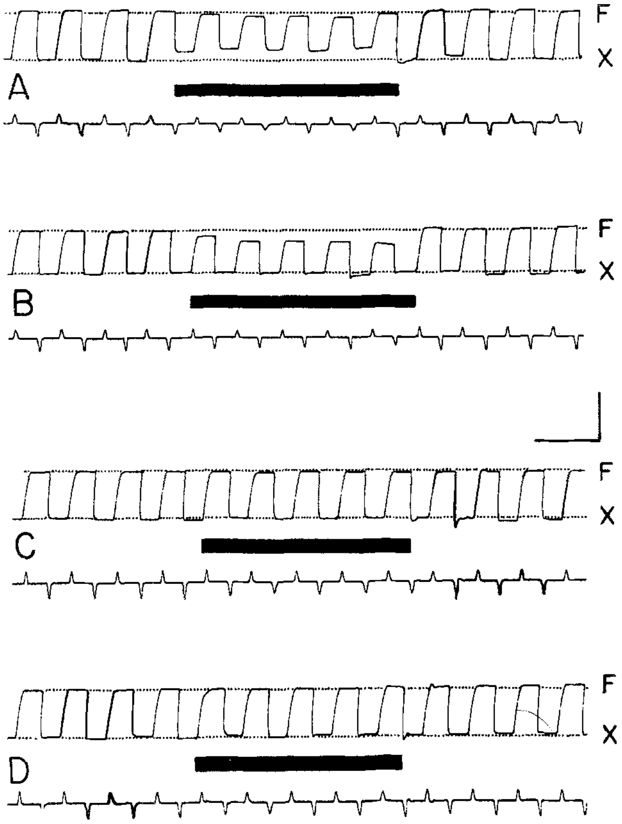

Fig. 1A–D. Effects of continuous muscle vibration during steptracking. In **A–D** are shown records of arm position (upper traces) and velocity (lower traces) during performance of steptracking movements. The dotted lines on the position traces indicate the positions of the targets being tracked (*F* – flexion; *X* – extension). Tendon vibration was applied during the period indicated by the solid bar under each position record. **A** and **B** are from a trial with no visual guidance (**A** – biceps vibration; **B** – triceps vibration). **C** and **D** are from trials in which the subject was given visual information as to arm position (**C** – biceps vibration; **D** – triceps vibration). The horizontal calibration represents 10 s and the vertical calibration for position and velocity are respectively 60 deg and 500 deg/s

with an eccentric head. The motor was enclosed in a metal case. The whole apparatus weighed 70 gm with dimensions 2 × 3 × 5 cm. Vibration frequency was adjustable and was set to 120 Hz (Burke et al. 1976; Hagbarth 1973). Vibration could be applied either continuously or only during flexion or extension movements as desired. During experimental trials the subjects were instructed to begin the steptracking movements and to continue doing so after the vibrator was activated.

Figure 1A shows the effects of biceps vibration applied during movements made without visual guidance. Vibration was applied continuously during the period marked by the solid bar. A marked undershoot of the extension target occurred and was maintained as long as the vibrator was activated. However, correct attainment of the flexion target was not affected. Conversely, triceps vibration (Fig. 1B) resulted in an undershoot of the flexion target but had no effect on the attainment of the extension target. Thus, vibration of the muscle antagonistic to the movement being performed resulted in an undershoot of the required target. In contrast, vibration of the muscle acting as the prime mover had no effect on the attainment of the required target.

The absolute magnitude of the positional error varied somewhat from subject to subject but was approximately 15–20 degrees for the 65 degree movements which were studied. The effect was seen in all subjects studied. Indeed, it was also seen in one of us (jdc) who had been an experimental subject several times, who well understood the effect of the vibration and who was actively trying to compensate for the action of the vibration.

The effect of the vibration could be overcome if the subject performed the movement under visual guidance, that is, if the subject were permitted to view the target and handle displays. Under these conditions no impairment of positioning was found during either biceps or triceps vibration (Fig. 1C, D). It might be noted that there was, during both visually and non-visually guided trials, a tendency for the movement velocity to decrease (Fig. 1). In addition, during visually guided trials the first few movements made during the vibration were often seen to fall short of the intended target. The target was subsequently reached by a small final corrective movement. When this occurred the error was always in the same direction as that during non-visually guided trials.

An exactly identical effect was observed if the vibration was applied only during movement. For these studies the vibrator was activated only when the velocity of handle movement was greater than a threshold level. The vibrator was thus turned on just after the start of the movement and turned off just before the arm came to rest in its final position. In the experiment illustrated in Fig. 2A, biceps vibration was applied during extensions, the subject performed the movements without visual guidance. As was seen with continuous vibration, an undershoot of the extension target occurred whereas the flexion target was correctly attained. In contrast, when biceps vibration was applied during flexions there occurred no error in the attainment of the flexion target (Fig. 2B). Equivalent effects were seen with triceps vibration during movement: an undershoot of the flexion target if vibration was applied during flexions and no effect when vibration was applied during extensions.

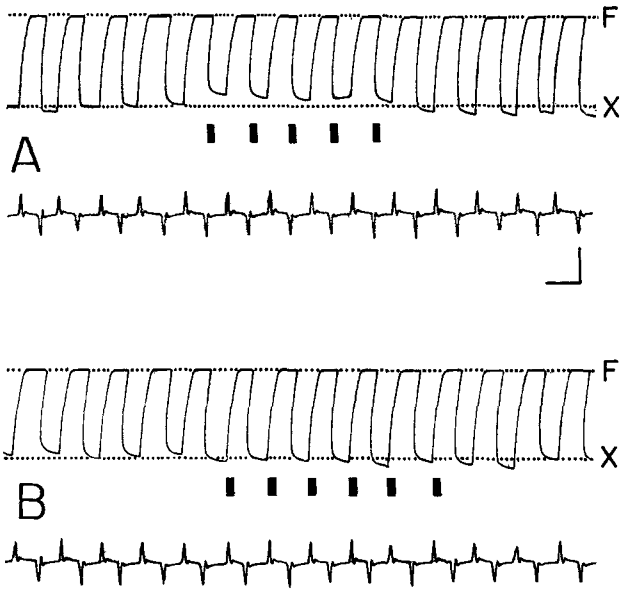

Fig. 2A, B. Effects of muscle vibration during step-tracking movements. Position and velocity records of step-tracking movements are shown. The dotted lines on the position records indicate the positions of the target being tracked (*F* – flexion; *X* – extension). Vibration of the biceps tendon occurred during those movements indicated by the solid rectangles below the position record. In **A** the vibration was applied during extension movements and in **B** during flexion movements. The horizontal calibration bar represents 5 s and the vertical bar 40 deg for position and 500 deg/s for position

Three points of interest can be made about the present results. First, muscle vibration can affect the attainment of final limb position during the performance of an active, voluntary movement. Second, vibration of the muscle antagonistic to a given movement affects the attainment of the final position resulting from that movement. Third, movement to a desired position can be affected by muscle vibration applied just during the course of that movement.

We propose that, for the type of movements studied, the CNS monitors muscle afferent activity of the lengthening (antagonist) muscle rather than the muscle which acts as the prime mover. The suggestion has indeed been made that such information may be handled via the interpositus nucleus of the cerebellum (MacKay and Murphy 1979; Thach 1978). Muscle vibration, which is known to activate muscle spindles (e.g., Burke et al. 1976; Hagbarth 1973) would thus 'misinform' the CNS about the limb position in a direction in agreement with the observed results. For example, during triceps vibration the increased muscle afferent activity from the triceps would indicate to the CNS that the triceps is longer than it actually is. This would correspond to an "over-flexed" forearm and therefore result in an undershoot of the flexion target.

The above proposal is consistent with observations of the behaviour of spindle afferents during rapid movements (Goodwin and Luschei 1975; Hagbarth et al. 1975; Lund et al. 1979). These authors report high-frequency spindle afferent discharge when the muscle of origin is stretched by an active movement. Moreover, they observed that spindle afferents from the contracting muscle were silenced during active shortening. The lack of effect of vibration of the agonist muscle during movement is consistent with these observations. This lack of response to what must be a very large stimulus (the vibration) suggests that spindle sensitivity is low during these rapid movements in spite of any alpha-gamma co-activation which may be present.

References

Burke D, Hagbarth KE, Löfstedt L, Wallin GB (1976) The responses of human muscle spindle endings to vibration of non contracting muscles. J Physiol (Lond) 261: 673–693

Goodwin GM, Luschei ES (1975) Discharge of spindle afferents from jaw-closing muscles during chewing in alert monkeys. J Neurophysiol 38: 560–571

Goodwin GM, McCloskey DI, Matthews PBC (1972) The contribution of muscle afferents to kinesthesia shown by vibration induced illusions of movement and by the effects of paralysing joint afferents. Brain 95: 705–748

Hagbarth KE (1973) 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. Karger, Basel, pp 428–443

Hagbarth KE, Wallin G, Löfstedt L (1975) Muscle spindle activity in man during voluntary fast alternating movements. J Neurol Neurosurg Psychiatry 38: 625–635

Lund JP, Smith AM, Sessle BJ, Murakami T (1979) Activity of trigeminal α- and γ-motoneurons and muscle afferents during performance of a biting task. J Neurophysiol 42: 710–725

McKay WA, Murphy JT (1979) Cerebellar influence on proprioceptive control loops. In: Massion J, Sasaki K (eds) Cerebro-cerebellar interactions. Elsevier, Amsterdam, pp 141–162

Thach WT (1978) Correlations of neural discharge with pattern and force of muscular activity, joint position, and direction of intended next movement in motor cortex and cerebellum. J Neurophysiol 41: 654–676

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