

Vibration-Induced Postural Posteffects

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Wierzbicka, M. M., J. C. Gilhodes, and J. P. Roll. Vibration-induced postural posteffects. *J. Neurophysiol.* 79: 143–150, 1998. It generally is known that vibration of various muscles in free-standing subjects evokes a spatially oriented postural response. Furthermore, it recently has been shown that when a vibratory stimulus is terminated, a powerful involuntary contraction of the previously vibrated muscle often occurs that, under the isotonic condition, is accompanied by movement of a limb. The aim of this study was to explore effects of a low-amplitude mechanical vibration, applied in a seated position, on the standing posture. The 30-s vibration was applied bilaterally at the ankle level to anterior or posterior tendons and at the cervical level in front or back of the neck, at one site only at a time. Center of pressure trajectories were monitored during quiet stance for ≤ 19 min after the offset of vibration, and these measurements were compared with a previbration control trial. The results clearly indicate that vibration produced in all subjects strong, long-lasting dynamical modification of posture mainly in the anterior-posterior direction. Spatial orientation of the induced postvibratory shift in posture was dependent on the vibration side. We conclude that sustained Ia sensory inflow, evoked by vibration, has a powerful after-effect on the motor system at the postural level.

INTRODUCTION

In recent years, a tendon vibration technique commonly has been used to elucidate the role of muscle spindles in movement coding and posture control. Such an approach allows an extension of a traditional view of reflex use of proprioceptive feedback in control of human posture and movement to a more flexible framework of integrated, context-dependent processing of afferent information (Cordo et al. 1995; Gurfinkel et al. 1988; Paillard 1988; Roll et al. 1986, 1991b). This technique is becoming particularly useful in studies of muscular proprioception because microneurographic recordings show that in the relaxed muscle, vibration predominately activates Ia afferents and that there is a one-to-one correspondence between muscle spindle discharges and the mechanical stimulus in the frequency range of ≤ 100 Hz (Burke et al. 1976; Roll and Vedel 1982; Roll et al. 1989). The sensitivity of muscle spindles to tendon vibration is dependent on the mechanical characteristics (force, displacement, and frequency) of a stimulus (Cordo et al. 1993). A properly designed vibratory stimulus could even be used to mimic the proprioceptive message originating from the muscle (Gilhodes et al. 1993). The activation of sensory input by applying tendon vibration can induce segmental and postural kinesthetic illusions, supporting the notion that proprioception contributes to awareness of posture and movement (Goodwin et al. 1972; Roll and Vedel

1982). The evoked illusory movement occurs in a direction that would produce stretching of the stimulated muscle if the actual movement were made. Asymmetric stimulation of agonist and antagonist muscles is essential for eliciting kinesthetic illusions. It was shown that covibration of the agonist and antagonist muscles at the same frequencies do not evoke illusions (Gilhodes et al. 1986; Roll and Vedel 1982).

A stimulation of the same muscle may produce various illusory movements dependent on the postural (Gurfinkel et al. 1993; Roll et al. 1986), cognitive (Feldman and Latash 1982a), and multisensory context (Lackner and Levine 1979). For example, switching from segmental to postural sensation is possible if the stimulated wrist muscle becomes functionally involved in the whole body posture such as in a case of leaning on the hand against the wall (Roll et al. 1986, 1991b). Therefore it was suggested that the decoding of specific proprioceptive information by the CNS is context dependent because not only local sensory input is involved, but also more global information is taken into account (Roll et al. 1991a). Furthermore, there is evidence that the nervous system integrates proprioceptive messages arising from different muscles because application of various spatio-temporal patterns of tendon vibration to wrist muscles can evoke complex movement illusions such as drawing of geometrical figures of different shapes (Roll and Gilhodes 1995).

Somatosensory input, in addition to visual and vestibular ones, is used by the nervous system in controlling human stance. An involvement of proprioception in regulation of vertical posture is demonstrated by evoked perceptual illusions (Hay 1996; Quoniam et al. 1992; Roll et al. 1991a) or whole body movements (Eklund 1969; Gregoric et al. 1978; Quoniam et al. 1995) when vibration is applied to tendon of various muscles in a standing position. The direction of the vibration-induced sway is dependent on the vibration side (Eklund 1972; Gilhodes et al. 1996; Gurfinkel et al. 1993; Lund 1980). This directional dependence of falling reaction could indicate a functional meaning of proprioceptive feedback. It has been suggested recently that in some muscles the proprioceptive feedback could have a regulatory function in posture control, in others an assistive one (Gilhodes et al. 1996). For example, it was shown that stimulation applied at the ankle induced a postural sway in the direction of the vibrated side, indicating reflex regulation as a subject tried to compensate for the simulated stretch of the vibrated muscle. A contrary instance would be the vibration of neck muscles. These produce the postural shift in a contralateral direction to the vibration side, suggesting motor assistance behavior associated with whole body orientation

(Roll and Roll 1988). The regulation of posture depends not only on proprioceptive messages arising from skeletal muscles but also from extraocular muscles. It was shown that vibration of eye muscles in a standing subject could evoke postural movements with similar directional dependence on the vibration side as in skeletal muscles (Roll and Roll 1989). Such findings indicate that extraocular proprioception is linked closely with spatial body orientation (Roll and Roll 1987; Roll et al. 1991a). These authors suggested that the proprioceptive chain from eye muscles to foot muscles is involved in controlling the human stance, provided that afferent signals from all linked body segments are coprocessed by the nervous system.

It is not only during vibration that sensory reference is modified (Feldman and Latash 1982b); it remains altered for some time after a stimulus is discontinued. In addition to those studies showing changes in the position sense after vibration (Rogers et al. 1985), there are also studies showing kinesthetic and motor postvibratory effects (Gilhodes et al. 1992). Similar posteffects were reported after prolonged, sustained isometric voluntary contractions (Craske and Craske 1986; Gilhodes et al. 1992; Hick 1953; Sapirstein et al. 1937). There are only a few psychophysiological and neurophysiological studies, and all of these are concerned with segmental posteffects. The present study is aimed at investigating postural postvibratory effects. In particular our goal was: to examine if activation of Ia afferents by muscle tendon vibration in a seated position can evoke motor posteffects that could be observed during quiet stance and to describe temporal and spatial characteristics of these posteffects. In addition, neural mechanisms responsible for the posteffect phenomenon and some possible applications are discussed.

METHODS

Twelve (6 female and 6 male) healthy subjects ages 23–59 participated in the study. First, 1 min of control data was recorded during erect standing on a force platform with hands hanging at the sides and eyes closed. After the control trial was completed, the subject was asked to sit on a chair with feet supported on the platform. This arrangement was chosen to minimize the subject's effort of changing position from seated to standing posture, which was important during postvibration recording because excessive movement may diminish the evoked posteffect (Hutton et al. 1987). While in a seated position with eyes closed, 30 s of vibration (frequency 80 Hz and amplitude of 0.2 mm) was applied directly to muscle tendons by means of inertial vibrators (VB 100 Dynatronic). Four vibration sites were used, but only one site was stimulated at a time to explore evoked posteffects.

Vibration was applied at the ankle level bilaterally to Achilles tendons or the tibialis anterior tendons and at the cervical level to the front (sterno-cleido-mastoidus tendons) or the back of the neck (trapezius and splenius tendons). Immediately after vibration ceased, the subjects were asked to stand up on the force platform, close their eyes, and relax. The subjects were assured that the investigator would protect them from falling should their balance become disturbed. Also each subject was told that our interests were in the long-term effects after the treatment with vibration. One minute of data was recorded, then the subject was allowed to rest on the chair for 2 min before another 1 min recording of data on the force platform. After each trial the electromyographic (EMG) and force data were displayed on a computer screen (Power

Macintosh 8100/80 AV). The repetition of this cycle, 1-min recording and 2-min rest, was continued until the posteffect vanished or time elapsed since termination of vibration exceeded 19 min (equivalent to 7 postvibration recordings). Because these four experiments, corresponding to four different vibration sites, generally were performed one after another, care was taken to assure that the subject had fully recovered from the previously induced posteffect. If necessary, the subject was asked to perform some light exercises in between experiments to speed up recovery. In one subject, each muscle was studied on separate days due to exceptionally long-lasting posteffects (~3 h).

Subjects were asked to describe the kinesthetic illusion that they may have experienced during vibration. The surface EMG from the tibialis anterior and from the soleus muscle were recorded to provide evidence for an evoked tonic vibration response or an antagonist vibration response. During quiet standing, with the left and right foot supported on two adjacent force platforms, the x - y coordinates of center of pressure (COP) trajectories were sampled at 50 Hz. The COP, which represents the location of the vertical ground reaction vector from the force platforms, was calculated based on measurements of four strain gauges located in the front and back of each force platform (Winter et al. 1996). The left back force transducer was taken as the origin of axes. The mean value (MN) and standard deviation (SD) of the $Y(t)$ coordinate of the COP were calculated for the control trial and postvibration trials. In addition, total time in which the subject was outside the range (MN - 2 SD, MN + 2 SD) of the control posture (before vibration) was evaluated for each postvibration trial.

RESULTS

Perceptual and motor effects during vibration

In most cases, subjects experienced, during vibration, a kinesthetic illusion of a body segment moving in a direction that would produce lengthening of the stimulated muscle (Table 1). The vibration-induced kinesthetic illusion effect could be felt locally, such as plantar flexion/dorsiflexion of the feet, or more globally as extension/flexion of the legs or sliding the chair backward/forward in the case of the tibialis anterior/soleus stimulation, respectively. Similarly, illusory head flexion/extension or trunk flexion/extension was reported during the cervical stimulation. In general, vibration of neck muscles evoked a weaker illusion than vibration of leg muscles, perhaps because at the cervical level muscles were tonically active during stimulation. In 30% of cases, the evoked kinesthetic illusion was accompanied by the tonic vibration response (TVR, i.e., contraction of the vibrated muscle) or the antagonist vibration response (AVR, i.e., contraction of the antagonist muscle in response to vibration of its agonist muscle) that could be observed in the concurrent EMG recording (Table 1). There was no clear relationship between TVR or AVR and the strength of the evoked kinesthetic illusions.

Motor effects after vibration

All subjects exhibited postvibratory modification of posture. Strong changes in the posture occurred mainly in the anterior-posterior (Y) direction and not in the mediolateral direction, as can be seen in the x - y plot of the COP trajectory from one subject for the tibialis anterior stimulation (Fig. 1A). The corresponding vibration-induced deviation of the posture in the sagittal plane versus time is shown in Fig.

TABLE 1. Summary data on muscle activation and illusion during vibration

Subject	Motor Response		Kinaesthetic Illusion			
	Tibialis	Soleus	Tibialis	Soleus	Neck back	Neck front
1	—	—	+++	++	+	—
2	TVR	AVR	+++	+++	+	—
3	—	—	+++	++	+	+
4	—	—	+++	++	+	—
5	—	—	+++	+	+	+
6	—	AVR	+++	++	+	—
7	AVR	—	+++	+++	++	—
8	—	AVR	+++	++	+	+
9	—	—	+++	+++	+	—
10	—	AVR	+++	+++	+++	++
11	—	—	+++	++	+	++
12	TVR	TVR	+++	++	—	—

Columns 2 and 3 indicate presence in the electromyographic recordings of tonic vibration response (TVR) or antagonist vibration response (AVR). Columns 4–7 provide rating of strength (+++, strong; ++, medium; +, weak) of experienced kinesthetic illusion.

1B. The selected trials illustrate the dynamic process of the evoked posteffect. Immediately after vibration (*recording 1*), the subject has difficulty in remaining at the control position (near the center of the platform) and is falling backward. When an extreme posture is approached, the subject

returns voluntarily to the control posture. Then again the subject “let go” and resumed drifting backward, as shown in recorded consecutive cycles. With the passage of time, the posteffect gradually disappears, as the last recording (*recording 7*) resembles the control trial (*recording 0*). Data (all 8 recordings) presented in the form of histograms (Fig. 2) indicate a narrow fairly symmetric histogram for the control trial and strongly skewed histograms after vibration with the last histogram shape similar to the control one, indicating the subject’s recovery from the post-effect. In Fig. 3 mean values (Y coordinate of COP), SD, and time the subject spends outside the range of the control position are plotted versus the trial number. It can be seen that the mean position of the COP was shifted strongly backward immediately after the tibialis vibration (*trial 1*) as compared with the control (*trial 0*) and was returned gradually to the initial value within the 19-min time interval. Also the SD of the COP was increased greatly after the vibration, and the subject spent most of time outside the control position.

In the majority of subjects (10 of 12), posteffects were evoked at all vibrated sites (Table 2). The direction of vibration-induced sway was clearly dependent on the vibration side as in the majority of subjects the shift in the mean COP position occurred in the same direction (Table 2). Summary data (subjects who had no posteffects or reversed posteffects were excluded) are presented in Fig. 4A for the ankle stimulation and in Fig. 4B for the neck stimulation. Most of the time, vibration of the tibialis anterior caused a backward shift in the mean position, whereas soleus vibration caused a forward shift of the mean position. The stimulation of the dorsal neck muscles produced, in general, a forward shift in the mean position, whereas stimulation applied at front of the neck caused a backward shift in the mean position.

Time-profiles of COP trajectories after vibration not only varied from trial to trial, as less frequent and/or weaker postural responses generally occur with increased time after vibration (Fig. 1B) but also varied between individuals. Subjects differed in the strategy employed to deal with the posteffect. For instance, two subjects did not correct their deviated posture at all, leaning strongly against the support provided by the experimenter during entire recording time. However, most subjects, as soon as they felt support, re-

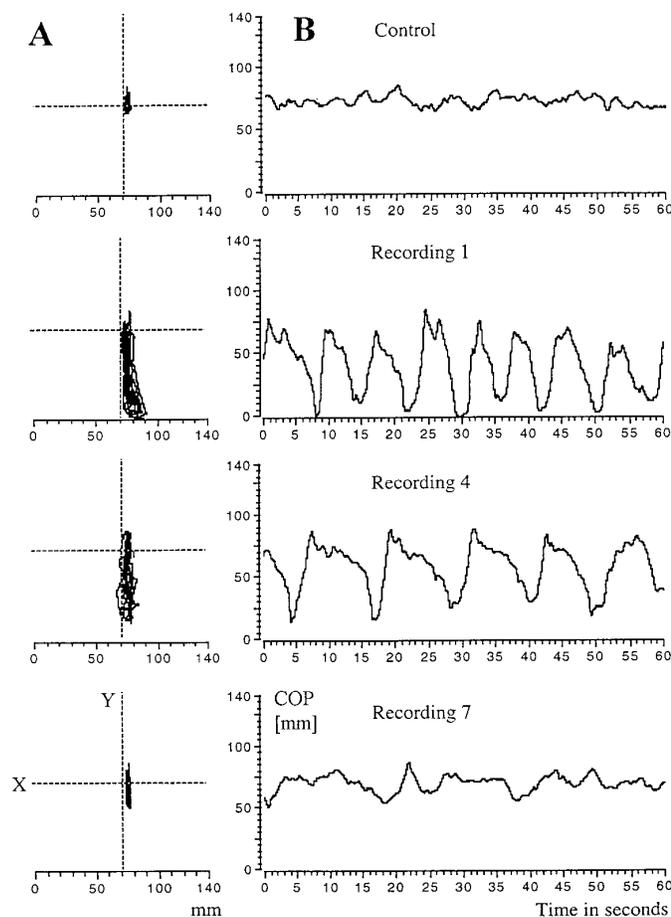


FIG. 1. Center of pressure (COP) trajectories recorded from 1 subject during quiet stance with eyes closed before vibration (control); immediately after (*recording 1*); 9 min (*recording 4*) and 18 min (*recording 7*) after the vibration offset. X-Y plot (A) and time profiles of the anteroposterior component of COP, i.e., Y vs. time (B).

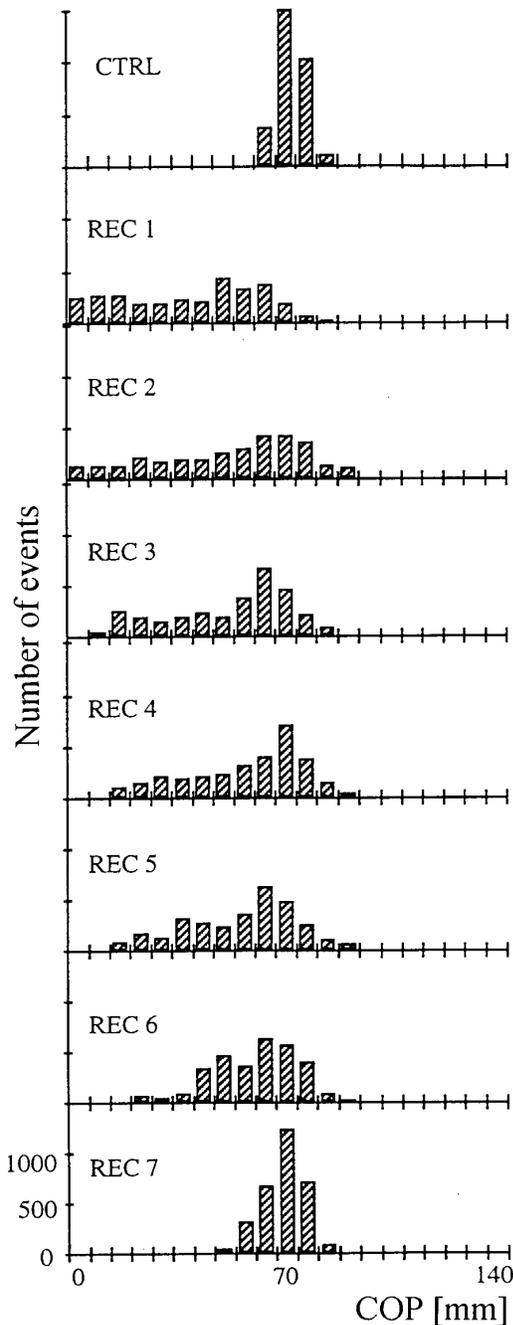


FIG. 2. Anteroposterior COP instantaneous positions recorded with 50-Hz sampling rate during 1-min time epochs are shown in the form of histograms. Control trial and 7 postvibration trials are presented for the same subject as in Fig. 1. In consecutive postvibration recordings, elapsed time since vibration offset is: 0, 3, 6, 9, 12, 15, and 18 min for trials 1-7, respectively.

turned voluntarily to the control position and after some time began to drift again (involuntary effect). Such strategy produced periodic motion in the anterior-posterior direction as shown in Fig. 1B. The down phase of recorded oscillations (Fig. 1B) corresponds to involuntary body sway, which is considered to be the posteffect. In other words, in both groups of subjects, vibration produced the same effect, which is directional shift in body posture. Strength and duration of

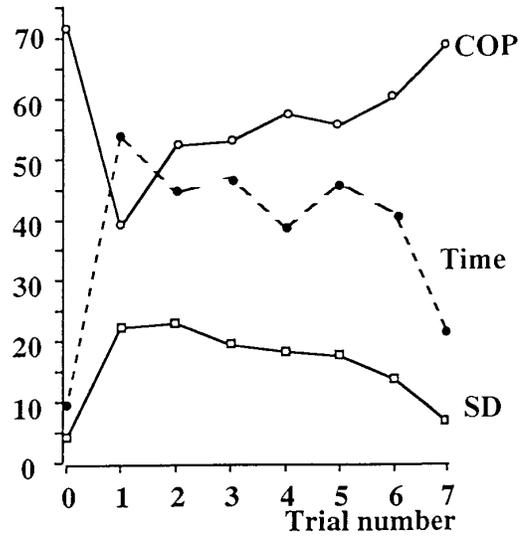


FIG. 3. Mean values of the anteroposterior COP position (—○—), standard deviation (—□—), and time spent outside the control posture (---●---) are plotted vs. trial number (0 = control trial, other numbers indicate consecutive postvibration trials, see legend in Fig. 2). Data are from the same subject as in Fig. 1. Vertical calibration: time in seconds, COP (Mean & SD) in mm.

the evoked posteffect also varied from subject to subject and within the same subject from muscle to muscle. There was an obvious relationship between intensity and duration of the posteffect: the larger the deviation of the mean COP from the control value after vibration, the longer the posteffect lasted (correlation coefficients: 0.78, 0.78, 0.73, and 0.66 for stimulation of tibialis anterior, soleus, neck back, and neck front, respectively, $P < 0.05$). In most cases, posteffects gradually waned (Fig. 2) during follow-up time, i.e., within 19 min, but in some subjects, these effects lasted longer, in an extreme case ≤ 3 h. The shortest duration posteffects were of $\sim 1-3$ min (apparent only in the first postvibration recording, Table 2). In all subjects, average mean position variability (expressed as SD) increased after vibra-

TABLE 2. Summary of directions and durations of posteffects

Subject	Tibialis	Soleus	Neck Back	Neck Front
1	B (3)	F (6)	F (1)	B (1)
2	B (4)	—	—	B (1)
3	B (7)	F (7)	B (7)	B (7)
4	B (4)	F (1)	—	—
5	B (6)	F (1)	F (4)	B (7)
6	B (4)	B (5)	F (4)	B (2)
7	B (7)	F (6)	F (6)	B (4)
8	B (5)	F (3)	F (4)	B (4)
9	B (2)	F (4)	F (5)	B (1)
10	B (1)	F (6)	F (6)	B (7)
11	F (4)	F (4)	B (3)	B (4)
12	B (4)	F (2)	F (1)	B (2)
Total	11/12 B	10/11 F	8/10 F	11/11 B

Vibrations-induced directional shift in the mean anteroposterior center of pressure (COP) position below (leaning backward "B") or above (leaning forward "F") the corresponding control, previbration, value. Numbers in parentheses indicate the number of postvibration trials in which posteffects were apparent. In all indicated trials, differences in mean values were statistically significant, $P < 0.05$, Newman-Keuls test. Bold symbols indicate that only a few subjects experienced posteffects in the opposite direction.

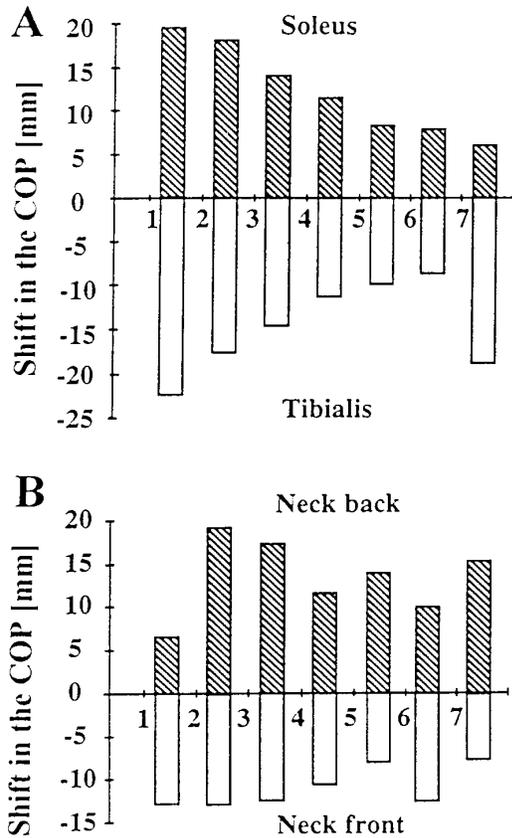


FIG. 4. Average (across-subjects) postvibratory shift in the mean anteroposterior COP position from the control value produced by 30 s of stimulation, applied to ankle tendons (A) and at the cervical level (B), plotted vs. trial number. There was a strong tendency to lean backward after the tibialis anterior vibration (□) and forward after the soleus vibration (■). Vibration applied in front of the neck produced, in general, after-effect of leaning backward (□) and in back of the neck of leaning forward (■).

tion was applied at any site (Fig. 5A), indicating a disturbance of posture control. Subjects tended to spend most of their time (Fig. 5B) outside the 95% limits of the initial posture fluctuation before vibration. It can be noted that in the pooled data from all subjects, both SD of the mean position and time outside control posture do not return to their previbration values during the recording period, as in Fig. 2 (recording from 1 subject), because subjects differ substantially in duration of their posteffects (Table 2).

DISCUSSION

Postural postvibratory responses

Short-lasting muscle tendon vibration (30 s) applied to a subject in a seated position evoked in all subjects long-lasting postvibratory modification of the posture. After vibration, subjects tended to lean forward or backward indicating a shift from control (vertical) posture. One can assume that these new body postures, outside the range of the normal erect posture, are generally less stable even if subjects are not exposed to vibration. Thus the observed effects rather than being produced by vibration could simply indicate increased postural oscillations when the boundary of a stable equilibrium is being approached. To clarify the issue of postural stability, we ran an

additional experiment in which vibration was not applied. We found no evidence of increased postural oscillations when subjects imitated the postvibratory posture, by voluntarily leaning forward or backward, as compared with the control posture. The COP recordings from one subject are shown in Fig. 6; data were consistent for all four subjects participated in the study. Moreover, our data indicate that the presence of a kinesthetic illusion and/or vibration response (TVR/AVR) seems not to be a necessary prerequisite to obtain observed posteffects (Tables 1 and 2).

The strength and duration of vibration-induced posteffects

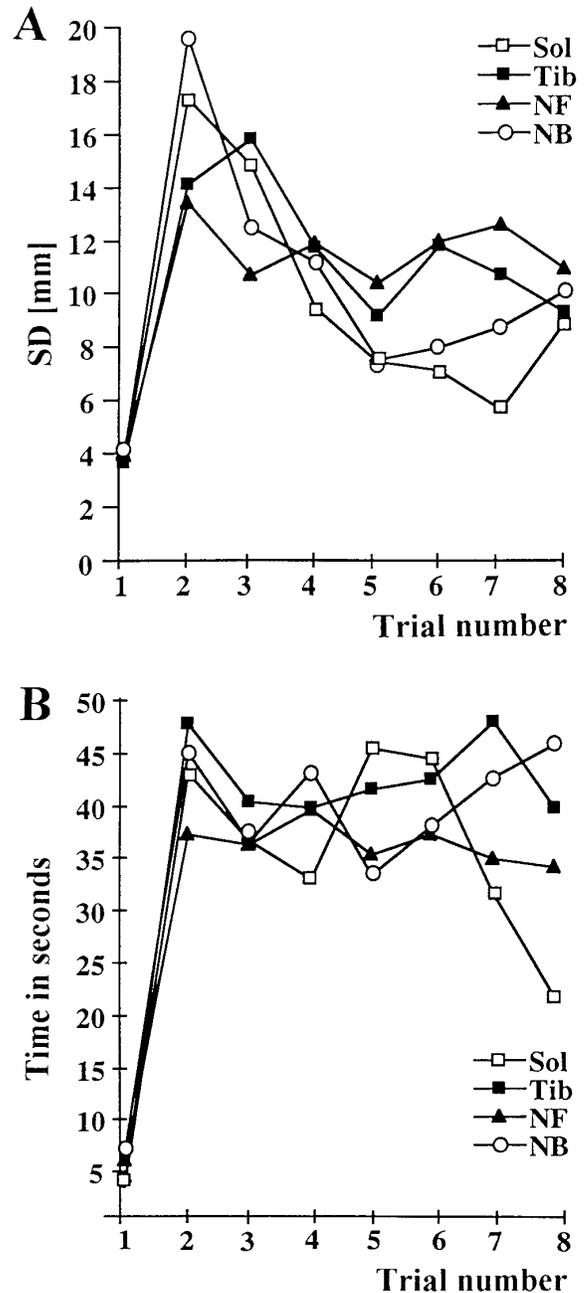


FIG. 5. SD of the anteroposterior COP position (A) and time spent outside the range of control posture (B). Each graph represents averaged data (12 subjects) corresponding to a different vibration site: tibialis anterior (■); soleus (□); neck back (○); neck front (▲).

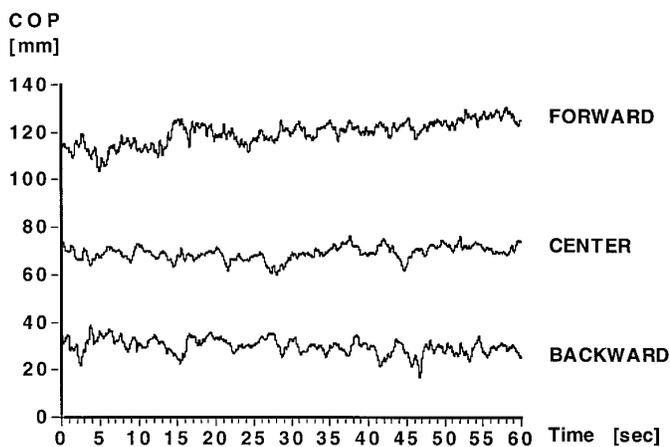


FIG. 6. Anteroposterior COP recordings in the normal erect posture (center) and when the subject voluntarily leaned forward or backward. Vibration was not applied.

varied across subjects and within the same subject from muscle to muscle. Such postural changes could last from 3 min to ≤ 3 h. In a few subjects, posteffects were not evoked at each stimulation site; they were absent mainly with the neck muscle vibration. These findings are consistent with an earlier description (Martin et al. 1980) of posteffects studied with use of a vibration platform and produced with much longer vibration exposure (30 min). It was shown that after whole-body or leg vibration, all subjects had difficulty in maintaining balance, but no significant postural changes were observed after head-trunk or head vibration. The postural posteffects examined in this study seem to be evoked more easily than segmental posteffects investigated before (Gilhodes et al. 1992). However direct comparison of these effects might be difficult due to different experimental conditions. In the current study, the previously vibrated muscles were engaged actively in maintaining posture, whereas in the segmental studies the arm was supported on a manipulandum, so muscular counteracting of gravity forces was not required.

An interesting feature of postural posteffects is their directional specificity in relation to the vibration side, which also was reported in earlier studies of segmental posteffects (Gilhodes et al. 1992). In only a few cases (8%), posteffects occurred in the opposite direction (Table 2). Several factors can account for such reversals. Previous studies indicate that vibration-induced kinesthetic and motor effects are context dependent. For example, involuntary activation of the previously vibrated muscle can be shifted to the antagonist muscle by a maneuver of closing the eyes (Gilhodes et al. 1992). Similarly, vibration-induced reflexes can be switched from the tonic vibration response to the antagonist response by withdrawing visual input (Feldman and Latash 1982a; Roll et al. 1980). Furthermore, Feldman and Latash (1982a) showed that kinesthetic illusions and vibration-induced reflex activity also can be reversed by auditory stimulation and that switching is dependent on the subject's attention, indicating involvement of both reflex and supraspinal pathways in mechanisms responsible for such transitions.

The phenomenon of postcontraction, first described by Kohnstamm (1915) and later confirmed by other investiga-

tors, resembles the postvibratory response. It is evoked by forceful isometric contraction maintained for some time; after this treatment involuntary movement of a limb occurs, usually in the direction of the previously exerted effort. Such movement is produced by involuntary activation of the same muscle after cessation of voluntary contraction. It was reported that the magnitude of the postcontraction is dependent on the strength and duration of contraction (Sapirstein et al. 1937). The postvibration and postcontraction responses have a number of similar features, such as the site at which involuntary postactivation occurs (previously vibrated or contracted muscle) and latencies at which they appear. Furthermore, both effects can be transferred from the agonist to the antagonist muscle by a visual input and can only be evoked with stimulation applied to one muscle of an antagonistic pair (Gilhodes et al. 1992).

Neurophysiological considerations

It is still unclear what neural structures are responsible for postvibratory and/or postcontraction phenomena. In addition to psychophysiological experiments, neurophysiological studies could provide some insight into these mechanisms. But currently the number of such studies, particularly those involving vibration-induced posteffects, is extremely limited. In one investigation, it was reported that after 30 s of muscle tendon vibration, an increase in resting discharge of muscle spindle primary endings never occurred (0/12), although concurrent involuntary activation of the previously vibrated muscle was observed in the recorded surface EMG (Ribot-Ciscar et al. 1995). These authors concluded that postvibration motor effects did not seem to be produced by proprioceptive postdischarges. In a subsequent single motor unit study, the same investigators addressed the question whether higher order neural structures are involved in involuntary muscle activation after vibration (Ribot-Ciscar et al. 1996). They showed that during postvibratory contractions and comparable voluntary contractions, recruitment and firing patterns of single motor units were similar, indicating that "postvibratory contraction may mainly involve a supraspinal tonic drive" otherwise peripheral facilitation of motoneurons after vibration should be observed (Ribot-Ciscar et al. 1996). Other investigators have showed that involuntary activation can occur not only at previously vibrated muscles (or its antagonists), but also can appear in muscles more distant from the vibration side (Gurfinkel et al. 1989). This finding suggests that the postvibratory phenomenon is not local, i.e., specific to the site of vibration, and thereby supports the involvement of supraspinal pathways. The altered position sense after vibration was said to indicate changes in central processing of the proprioceptive input (Rogers et al. 1985). From the point of view of modeling of neuromuscular systems, it is plausible that vibration of the muscle tendon produces disruption in evaluation of afferent and/or efferent inputs involved in the perception of limb position (Feldman and Latash 1982b). In the current study, some subjects reported feeling that their reference of the vertical posture was modified by vibration, thus they tended to adjust their posture to a new equilibrium position.

As currently viewed, postvibratory and postcontraction

effects are considered to be of similar origin; thus, further explanation can be sought from more extensive data on the postcontraction studies. In addition to the previously described motor postcontraction effects, sensory changes also were reported and various explanations of these findings were provided. Earlier animal studies showed a rise in the resting Ia neural activity after the offset of tetanic fusimotor stimulation (Gregory et al. 1986; Hutton and Suzuki 1979). In microneurographic recordings from humans, some investigators reported prolonged (8–240 s) postcontraction increase in sensory discharge above the resting precontraction level in about one-third of recorded Ia afferents that they assumed to be caused by changes in mechanical properties of the muscle (Wilson et al. 1995). These authors suggested that during the contraction phase, because of increased fusimotor drive, cross-bridges were disrupted and then reformed at the shorter muscle length. If this were so, the observed postcontraction discharges would be produced by the stretch of intrafusal fibers when the muscle began to relax (Wilson et al. 1995). Other investigators did not observe overall changes in the resting discharge, but instead reported decreased stretch threshold and also some loss of dynamic sensitivity of muscle spindle primary endings (Hagbarth et al. 1985; Ribot-Ciscar et al. 1991; Smith et al. 1974). It was suggested that these findings could be attributed to the prolonged fusimotor activation lasting beyond the muscle contraction (Ribot et al. 1986). This could prevent intrafusal slack after the contraction, so temporary disengagement of muscle receptors in coding movement could be avoided (Ribot-Ciscar et al. 1991). The idea of continuation of fusimotor drive after the cessation of voluntary contraction supports the concept that postcontraction is likely to be of a central origin rather than of a peripheral or spinal one. After-contraction, for a long time, was considered to be linked to supraspinal mechanisms, i.e., sustained excitation of cortical neurons (Sapirstein et al. 1937). Moreover, it was assumed that a motor postimage persists in the motor cortex in a similar way as ‘hallucinatory after-images produced by an intense sound or a bright light’ (Salmon 1916, cited in Sapirstein et al. 1937). Modification of excitability of central program generators also was suggested in connection with an oscillatory posteffect (Craske and Craske 1986). It is likely that, as in the case of a voluntary movement, central and peripheral neural structures can contribute together to the generation of the postcontraction phenomenon.

Whatever the mechanisms responsible for posteffects, the most important finding of this study is to show that the vibration-induced sustained Ia sensory discharge produces powerful prolonged effects on the motor system at the postural level. It is possible to think of posteffects as reflecting long-lasting consequences of motor actions. Thus it implies that there is some kind of memory of the previous motor activity within the nervous system (Neiger et al. 1986). From this point of view, vibration induced posteffects could have potential applications in rehabilitation medicine. It recently was shown that proprioceptive sensory stimulation can improve upper body posture in children with cerebral palsy (Redon-Zouiteni et al. 1994).

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