Difference in aftereffects following prolonged Achilles tendon vibration on muscle activity during maximal voluntary contraction among plantar flexor synergists

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Ushiyama, Junichi, Kei Masani, Motoki Kouzaki, Hiroaki Kancheisa, and Tetsuo Fukunaga. Difference in aftereffects following prolonged Achilles tendon vibration on muscle activity during maximal voluntary contraction among plantar flexor synergists. J Appl Physiol 98: 1427–1433, 2005. First published December 3, 2004; doi:10.1152/japplphysiol.00613.2004.—It has been suggested that a suppression of maximal voluntary contraction (MVC) induced by prolonged vibration is due to an attenuation of Ia afferent activity. The purpose of the present study was to test the hypothesis that aftereffects following prolonged vibration on muscle activity during MVC differ among plantar flexor synergists owing to a supposed difference in muscle fiber composition. The plantar flexion MVC torque and surface electromyogram (EMG) of the medial head of gastrocnemius (MG), the lateral head of gastrocnemius (LG), and the soleus (Sol) were recorded in 13 subjects before and after prolonged vibration applied to the Achilles tendon at 100 Hz for 30 min. The maximal H reflexes and M waves were also determined from the three muscles, and the ratio between H reflexes and M waves (H/Mmax) was calculated before and after the vibration. The MVC torque was decreased by 16.6 ± 3.7% after the vibration (P < 0.05; ANOVA). The H/Mmax also decreased for all three muscles, indicating that Ia afferent activity was successfully attenuated by the vibration in all plantar flexors. However, a reduction of EMG during MVC was observed only in MG (12.7 ± 4.0%) and LG (11.4 ± 3.9%) (P < 0.05; ANOVA), not in Sol (3.4 ± 3.0%). These results demonstrated that prolonged vibration-induced MVC suppression was attributable mainly to the reduction of muscle activity in MG and LG, both of which have a larger proportion of fast-twitch muscle fibers than Sol. This finding suggests that Ia-afferent activity that reinforces the recruitment of high-threshold motor units is necessary to enhance force exertion during MVC.

Ia-afferent activity; electromyogram; H reflex

THE MUSCLE SPINDLE BEHAVES not only as a receptor of muscle stretch but also as a sensor of motor signals during contraction (8–10, 40). Additionally, because α- and γ-motoneurons are coactivated, the Ia afferent is activated even during isometric voluntary contraction (49). Because the Ia afferent discharge increases with the strength of contraction (32), this fusimotor-driven Ia afferent activity originating from the muscle spindle has been considered to reinforce the excitatory drive of α-motoneurons in powerful force production. Several studies have suggested that Ia afferent inputs to the α-motoneuron pool augment muscle strength during maximal voluntary contraction (MVC) in a variety of muscle groups, such as plantar flexors (2, 37, 47), dorsiflexors (6, 7, 23), and knee extensors (28, 31).

A mechanical vibration to the muscle or tendon excites the muscle spindle primary endings (7, 9, 10, 17, 23). Notably, a high-frequency vibration can activate the Ia afferent selectively, whereas II and Ib afferents are either insensitive or only slightly sensitive to such a stimulus (9, 10, 42). Thus a mechanical vibration to the muscle or tendon affects several neurophysiological functions that are mediated by the Ia afferent activity, such as proprioceptive illusions (21), involuntary contraction of the vibrated muscles (tonic vibration reflex) (6), and the depression of the monosynaptic reflexes due to presynaptic inhibition (17).

As for voluntary contraction, the contraction force is modified by this vibration owing to the alternation of Ia afferent activity levels. Notably, the duration of the application of the vibration is an important factor in determining the degree of the modification of the contraction force. When the vibration is applied to the contracting muscle or its tendon for a few seconds, the contraction force is reinforced because of the augmentation of Ia afferent inputs to α-motoneurons. In fact, Hagbarth et al. (23) demonstrated that muscle vibration overcomes an attenuated contraction force induced by an anesthetic muscle nerve block that lowered fusimotor-driven Ia afferent inputs to α-motoneurons during MVC.

However, when a mechanical vibration is applied for a prolonged period, the force-generation capacity is attenuated because prolonged vibration induces the suppression of Ia afferent activity. It was reported that a prolonged superimposed vibration (>10–20 s) accentuates the fatigue-induced decline in contraction force during sustained dorsiflexion MVC (7). Our laboratory’s recent study (31) showed that the MVC force of knee extensor muscles decreases as an aftereffect of prolonged vibration to a single synergist muscle for 30 min. In addition, Thompson and Belanger (47) demonstrated that prolonged vibration induced by inline skating results in a depression of MVC force of plantar flexors. As a mechanism of prolonged vibration-induced MVC suppression, Bongiovanni et al. (7) discovered that the firing rates of high-threshold motor units progressively decline to a larger extent than those of low-threshold motor units during MVC due to prolonged vibration. In view of Henneman’s size principle (25), they argued that prolonged vibration-induced MVC suppression is attributed to the attenuated recruitment of the high-threshold

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motor units that supply powerful, fast-twitch muscle fibers (12, 13, 34, 36). Hence, they suggested that fusimotor-driven Ia-afferent activity makes a significant contribution to the recruitment of high-threshold motor units during MVC.

Considering these findings, it is hypothesized that the aftereffects following prolonged vibration on muscle activity during MVC differ among muscles that have different muscle fiber type compositions. Plantar flexors are one of the best suited synergists to test the hypothesis, because they have a remarkably different fiber-type composition in contrast with other synergistic muscle groups in humans (29, 43). The gastrocnemius muscle has 50–70% type II muscle fiber, whereas the soleus (Sol) muscle has 80–100% type I muscle fiber in humans (29, 43). Thus if the contribution of Ia-afferent activity to the reinforcement of the muscle activity during MVC is more significant in the muscle that has a larger proportion of fast-twitch muscle fibers, it is supposed that the suppression of the muscle activity induced by prolonged vibration will be more prominent in the gastrocnemius muscle than in the soleus muscle.

The aim of the present study was to investigate the hypothesis that the aftereffects following prolonged vibration on muscle activity during MVC differ among plantar flexor synergists because of a supposed difference in muscle fiber composition. This work has been partially presented in abstract form (48).

METHODS

Subjects. Thirteen healthy male subjects participated voluntarily in this study. Their age, height, and body mass ranged 22–49 yr, 162.5–178.2 cm, and 60.0–80.4 kg, respectively. They had no history of neurological disorders. All subjects gave their informed consent to participate in the study after receiving a detailed explanation of the purpose, potential benefits, and risks involved. The experimental procedures used in this study were in accordance with the ethical standards of the Committee on Human Experimentation at the Department of Life Sciences, The University of Tokyo.

Torque and surface electromyogram recordings. The subjects were comfortably seated in a semireclining position, and the right leg was fixed with the knee at 0° (fully extended position) and the ankle at 0° (neutral position) (Fig. 1). The foot was strapped to a plate to which a strain gauge was attached 15 cm from the ankle rotation axis. The upper body and thigh were also strapped to the chair so that subjects maintained a stable posture throughout the experiment.

The isometric plantar flexion force was measured by use of a strain gauge (LTZ-500KA, Kyowa, Tokyo, Japan) coupled to a strain amplifier (YB-503A, Kyowa). The axis of the ankle was aligned with that of the footplate as precisely as possible. Torque at the ankle joint was calculated on the basis of the measured force multiplied by the perpendicular distance between the strain gauge and the axis of the footplate. Surface electromyograms (EMGs) were recorded from the medial heads of the gastrocnemius (MG), the lateral heads (LG) of the gastrocnemius, the Sol, and the tibialis anterior (TA), over the muscle bellies, by using bipolar Ag-AgCl electrodes with a diameter of 5 mm and an interelectrode distance of 20 mm. The reference electrode was placed on the medial malleolus. The EMG signals were amplified (model 1253A, NEC Medical Systems, Tokyo, Japan) with band-pass filtering between 5 Hz and 1 kHz. All electric signals were stored with a sample frequency of 2 kHz on the hard disk of a personal computer using a 16-bit analog-to-digital converter (PowerLab/16SP, ADInstruments, Sydney, Australia).

Stimulation procedures. The stimulus for eliciting the H reflex and the motor action potential (M wave) from each of the plantar flexors was delivered as a 1-ms rectangular pulse from a digital stimulator (SEN-7203, Nihon Koden, Tokyo, Japan) in series with a stimulus-isolation unit (SS-1963, Nihon Koden). The cathode, a 3.5-cm² Ag-AgCl surface electrode, was placed cutaneously over the tibialis nerve in the popliteal fossa. The anode, a 24-cm² plate ground electrode, was placed on the ventral aspect of the knee, just proximal to the patella.

We elicited H reflexes from plantar flexors according to the method developed by Löscher et al. (33) and Cresswell and Löscher (14). At rest, the stimulus intensity was increased in gradual steps until the maximal amplitude of the H reflex in the resting Sol was found. By using this stimulus intensity, we were able to 1) activate the greatest possible number of Ia afferents in Sol and 2) record approximately maximal H reflexes in both heads of the gastrocnemius muscles (33). Because the H reflexes of MG and LG could not be elicited in some subjects, the subject number was different among muscles. The H reflexes of MG and LG could be successfully recorded from seven and nine subjects, respectively, whereas the Sol H reflex was recorded from all 13 subjects.

To elicit the maximal amplitude of the M wave (Mmax) from each of the plantar flexors, the supramaximal stimulus intensity was determined at rest by increasing the current stepwise until the last of the three muscles peaked in Mmax. The stimulus intensity was then increased by an additional 20%. By using this supramaximal stimulus intensity, the Mmax of the three muscles and the twitch were elicited simultaneously.

Vibration. Tonic vibration was applied for 30 min perpendicular to the Achilles tendon by a mechanical stimulator (DPS-285, Dia Medical System, Tokyo, Japan) with the shaft in a plastic tube. The top of the vibrator shaft was attached to the Achilles tendon 1 cm distal from the myotendinous junction of Sol. The myotendinous junction of Sol was determined visually with an ultrasonic apparatus (SSD-2000, Aloka, Tokyo, Japan). In previous studies using microelectrode recordings from human proprioceptive fibers (9, 10, 42), the Ia afferent was found to be most sensitive to the mechanical stimulus. In addition, vibration at a frequency of 80–100 Hz activated the greatest number of Ia afferents. In contrast, II and Ib afferents were found to be either insensitive or only slightly sensitive to such a high-frequency vibration (9, 10, 42). To stimulate Ia afferents selectively, therefore,
the vibration frequency was controlled at 100 Hz by a multifunctional synthesizer (D:506912–2, NF Electronic Instruments, Yokohama, Japan). The initial force level of the vibration was controlled by adjusting the screw bolt attached to the bottom of the vibrator. Then the force and peak-to-peak amplitude of the vibration were set at 10–15 N and 1.5 mm, respectively.

**Experimental protocol.** Before the execution of the experiment, each subject was fully trained to generate an isometric plantar flexion MVC for 1 wk. In the experiment, 10 resting H reflexes, each separated by 1 s, were elicited from the MG, LG, and Sol. With a 10-s interval after the last H reflex stimulus, three Mmax, each separated by 8 s, were evoked. When the Mmax was evoked, twitch torque was recorded simultaneously. After these resting stimulations, subjects performed three MVCs lasting 3 s each, with a rest of 1 min between each trial. After MVC measurements, tonic vibration was applied to the Achilles tendon for 30 min. During application of the vibration, subjects were instructed to relax their leg muscles, and we checked their EMGs to ascertain that no tonic vibration reflex was evoked in the plantar flexors. Immediately after cessation of the prolonged vibration, resting stimulations and MVC measurements were performed again. After prolonged vibration, the stimulus intensity for eliciting H reflexes from plantar flexors was determined again with the same procedure used in the previbration period because prolonged tendon vibration might change the firing threshold of Ia afferents (24).

Several studies demonstrated that prolonged vibration for more than 20 min induces a long-lasting depression of the Sol H reflex over 20 min (24, 47). In our experimental setup, we ascertained in preliminary experiments that it took 20 min on average for the complete recovery of H reflexes and MVC torque to previbration values and 10 min for a recovery to half the previbration values. However, the recovery time course varied across subjects. To evaluate effects of the vibration on H reflexes and MVC in quite a short period, therefore, we decided to execute the tests within 5 min after the cessation of the vibration.

The prolonged vibration employed in this study may involve a prolonged maintenance of body posture. To investigate whether this affects H reflexes, Mmax, twitches, and MVCs, the same procedures as for the vibration protocol were followed in all subjects before and after prolonged seating for 30 min without vibration. These control experiments were performed on a separate day. Vibration and control experiments were studied in a randomized order among subjects.

**Data analysis.** Simultaneous recordings of torque and EMG signals during MVC were analyzed over a 1-s period of stable torque output. The mean value of torque during each MVC was determined. EMG signals were full-wave rectified, and the mean amplitude of EMG (mEMG) during each MVC was determined. The torque and mEMG were averaged for each set of the three trials. Peak-to-peak amplitude was determined for all H and M potentials. The average of each set of 10 H reflexes and 3 M waves was calculated. Furthermore, because neuromuscular transmission-propagation failure would affect the amplitude of both H and M potentials (14, 33), the ratio between the amplitudes of H reflex and Mmax (H/Mmax) for each set was calculated. Twitches were analyzed as the following: 1) peak torque (PT); 2) contraction time (CT), the time to the maximal twitch torque; and 3) half relaxation time (HRT), the time taken to recover from maximal twitch torque to half-maximal twitch torque. Each of these parameters was averaged for each set.

**Statistics.** Values are given as means ± SE. MVC torque and each parameter for the twitch were analyzed by using a two-way ANOVA (2 experimental conditions × 2 times) with repeated measures. The mEMG values during MVC were analyzed by using a three-way ANOVA (2 experimental conditions × 2 times × 4 muscles) with repeated measures. Mmax was analyzed by using a three-way ANOVA (2 experimental conditions × 2 times × 3 muscles) with repeated measures. Because an analysis for H/Mmax included a within-subjects factor and a within-subject factor owing to the difference in number of subjects among muscles, H/Mmax was analyzed by using a mixed-model ANOVA (2 experimental conditions × 2 times × 3 muscles).

To test the differences in the percent change in MVC torque and each parameter for the twitch between experimental conditions, a paired Student’s t-test was used. The percent change in mEMGs was analyzed by using a two-way ANOVA (2 experimental conditions × 4 muscles) with repeated measures. The percent change in Mmax was analyzed by using a two-way ANOVA (2 experimental conditions × 3 muscles) with repeated measures. The percent change in H/Mmax was analyzed by using a mixed-model ANOVA (2 experimental conditions × 3 muscles). An α level of 0.05 was chosen for all statistical analyses with post hoc comparisons (Tukey’s test) when appropriate. All statistical analyses were performed with use of Statistica software (StatSoft).

**RESULTS**

**Torque and EMG activities of plantar flexors during MVC before and after prolonged vibration.** Figure 2A illustrates typical recordings of plantar flexion torque and full-wave rectified EMGs of MG, LG, Sol, and TA during MVC before and after prolonged vibration. The decline in MVC torque due to prolonged vibration is clearly accompanied by a change of EMGs especially in MG and LG.

The MVC torque decreased after the prolonged vibration by 16.6 ± 3.7% (189.3 ± 5.4 to 158.1 ± 8.3 N·m, P < 0.05) (Fig. 2B). The mEMGs of MG and LG decreased after the vibration by 12.7 ± 4.0 and 11.4 ± 3.9%, respectively (MG, 250.8 ± 18.0 to 218.6 ± 20.3 μV, P < 0.05; LG, 238.6 ± 19.8 to 208.7 ± 19.6 μV, P < 0.05) (Fig. 2C). In contrast, no statistically significant change was observed in the mEMG of Sol after the vibration (261.4 ± 11.5 to 252.5 ± 13.9 μV, P = 0.473) (Fig. 2C). The mEMG of TA, which is the antagonist of plantar flexors, also did not change with prolonged vibration (32.9 ± 2.4 to 30.6 ± 2.3 μV, P = 0.363) (Fig. 2C). Moreover, the magnitude of the decrease in mEMG values due to the vibration was larger in MG (12.7 ± 4.0%) and LG (11.4 ± 3.9%) than in Sol (3.4 ± 3.0%) (P < 0.05) (Fig. 2C).

We also examined the influence of prolonged maintenance of body posture on MVC torque and EMG activity in the control experiment. No difference between before and after prolonged maintenance of body posture was found in MVC torque (P = 0.705) (Fig. 2B) or mEMGs of any muscles (MG, P = 0.363; LG, P = 0.127; Sol, P = 0.111; TA, P = 0.240) (Fig. 2C).

**H reflexes of plantar flexors before and after prolonged vibration.** Representative examples of the H reflexes of plantar flexors before and after prolonged vibration are shown in Fig. 3A. We can clearly observe that the amplitudes of H reflexes were depressed owing to prolonged vibration in all three muscles. The H/Mmax decreased as a result of prolonged vibration for all three muscles (MG, 0.231 ± 0.071 to 0.147 ± 0.043, P < 0.05; LG, 0.274 ± 0.037 to 0.174 ± 0.036, P < 0.05; Sol, 0.450 ± 0.048 to 0.310 ± 0.057, P < 0.05) (Fig. 3B). In addition, the magnitude of the decline in H/Mmax did not differ among the three muscles (MG, 34.0 ± 8.2%; LG, 38.6 ± 8.4%; Sol, 36.1 ± 8.1%).

In the control experiment, no statistically significant change in H/Mmax was observed in any of the three muscles (MG, P = 0.305; LG, P = 0.695; Sol, P = 0.805) (Fig. 3B).

**Mmax and twitches before and after prolonged vibration.** The amplitude of Mmax did not change with prolonged vibration in any plantar flexors (MG, P = 0.526; LG, P = 0.819;...
Sol, \( P = 0.825 \) (Fig. 4A). Likewise, no statistically significant change was observed in each parameter for the twitch after prolonged vibration (PT, \( P = 0.209 \); CT, \( P = 0.592 \); HRT, \( P = 0.533 \)) (Fig. 4B). In the control experiment, prolonged maintenance of body posture for 30 min also did not influence the Mmax (MG, \( P = 0.444 \); LG, \( P = 0.874 \); Sol, \( P = 0.197 \)) (Fig. 4A) or any parameter of the twitch (PT, \( P = 0.134 \); CT, \( P = 0.201 \); HRT, \( P = 0.559 \)) (Fig. 4B).

DISCUSSION

The main finding of this study is that prolonged vibration-induced MVC suppression was accompanied by a reduction of EMG activity in MG and LG, whereas no change was observed in Sol. This finding supports our hypothesis that the aftereffects following prolonged vibration on muscle activity during MVC differ among synergistic muscles because of a supposed difference in muscle fiber composition.

Prolonged vibration-induced attenuation of Ia-afferent activity in plantar flexors. Before discussing the main finding here, we should comment on whether the prolonged vibration employed in this study successfully attenuated the Ia-afferent activity of plantar flexors. On the basis of previous results obtained from microneurographic recordings in humans (9, 10, 42), it was demonstrated that a high-frequency vibration similar to the one employed in this study gives rise to an intense discharge in Ia afferents, whereas II and Ib afferents show only a slight sensitivity to such a vibration. It was also demonstrated that the Ia-afferent activity is attenuated when a high-frequency vibration is applied for a prolonged period (7). This attenuation has been considered the result of mechanisms such as the presynaptic inhibition of Ia terminals (27), an increased firing threshold of Ia-afferent fibers (24), and the transmitter depletion at Ia synapses (16). In this study, Ia inputs to the α-motoneurons in plantar flexors were monitored indirectly by...
assessing the H reflexes before and after prolonged vibration. As a result, the H/Mmax significantly decreased after prolonged vibration for all plantar flexors (Fig. 3B). These results suggest that the prolonged vibration employed in this study successfully attenuated the Ia-afferent activities in all plantar flexors (38).

To execute the postvibration tests within 5 min after the termination of the vibration, we adopted a short interstimulus interval of 1 s for eliciting H reflexes. It was reported that a short interstimulus interval of <8 s leads to a low-frequency depression of H reflexes (15). However, the effects of this low-frequency depression have not been evaluated across synergists to date. Therefore, although H/Mmax was considerably attenuated in all plantar flexors similarly, we cannot exclude the possibility that the degree of attenuation differed among synergists because any difference in the rate of low-frequency depression among synergists could be masked in means of 10 H reflexes. There is room for further investigation regarding the effect of the low-frequency depression across synergists.

Difference in aftereffects following prolonged vibration on EMG activity during MVC among plantar flexors. In contrast with the above-mentioned H reflex results, it is of interest to note that the EMG activity during MVC was significantly reduced after prolonged vibration only in MG and LG, but not in Sol (Fig. 2C). Because the excitatory input from Ia afferents to the α-motoneuron pool was reported to be higher in type I muscle fibers than in type II muscle fibers (11), one might expect the effects of the attenuation of Ia-afferent activity due to the vibration to be more prominent in the EMG activity of Sol than in that of MG and LG. However, the EMG activity of Sol during MVC was not influenced by an attenuated Ia-afferent function due to the prolonged vibration, whereas that of MG and LG was. This surprising result can be explained by the contribution of Ia-afferent activity to the recruitment of high-threshold motor units during MVC as discussed below. Bongiovanni et al. (7) demonstrated that prolonged vibration-induced MVC suppression is primarily caused by the derecruitment of high-threshold motor units and not by the low-threshold motor units. Therefore, they suggested that Ia-afferent activity makes a significant contribution to the recruitment of high-threshold motor units during MVC. Our laboratory’s recent study (31) found that prolonged vibration applied to the rectus femoris muscle induces a significant decline in force development at the initial phase of knee extension MVC. This result also supports the idea that prolonged vibration-induced decline in Ia-afferent activity limits the excitation of high-threshold motor units. Because high-threshold motoneurons supply powerful, fast-twitch muscle fibers (12, 13, 34, 36), it is understandable that a reduction of EMG activity due to the vibration was observed only in MG and LG, both of which have more type II fibers than Sol (29, 43). Thus prolonged vibration-induced MVC suppression would be attributable mainly to a reduction of the EMG activity especially in MG and LG because of the attenuated recruitment of high-threshold motor units. As judged from these results, it is suggested that fusimotor-driven Ia-afferent activity that reinforces the recruitment of high-threshold motor units plays a more important role in MG and LG than in Sol during plantar flexion MVC.

Furthermore, there is a possibility that the prolonged vibration employed in this study affected the heteronymous Ia projections between synergistic muscles. Previous studies strongly suggested the existence of an Ia-mediated disynaptic inhibition from MG to Sol motoneurons in humans (22, 44). According to these reports, conditioning stimulation of the MG nerve resulted in a short-latency and short-lasting period of inhibition of the Sol H reflex. In addition, this inhibition of the Sol H reflex was abolished as a result of long-term (25 min) vibration applied to the Achilles tendon, suggesting the existence of an inhibitory effect of the Ia afferents from MG onto Sol motoneuron pool (22). From these findings, it has been considered that gastrocnemius muscles can be either agonists or antagonists of Sol in different tasks. In this study, although the H/Mmax of Sol significantly decreased, no change was observed in the EMG activity of Sol during MVC after the vibration. If the Ia-afferent activity of gastrocnemius muscles involves an activation of Ia interneurons inhibitory to Sol motoneurons during plantar flexion MVC, prolonged vibration would also attenuate this heteronymous inhibitory function. Therefore, the absence of change in the EMG activity of Sol after the vibration might be related partly to the attenuation of an inhibitory effect of the Ia afferent from gastrocnemius muscles onto the Sol motoneuron pool.

Other possible explanations for prolonged vibration-induced MVC suppression. There are other possibilities that may be related to prolonged vibration-induced MVC suppression: neuromuscular propagation failure (18), muscle fatigue status (18), compliance of the muscle-tendon unit (19), and motor cortex excitability (30, 46).

In this study, Mmax remained unchanged in all three muscles before and after prolonged vibration (Fig. 4A). Because M waves are initiated by action potentials that begin in the motor axons at the level of mixed nerves or muscle nerves, a change
in M waves indicates an alternation in neuromuscular propagation between the site of initiation (nerves) and the site of the recording (muscle fibers) (17). Indeed, many previous studies showed that long-term sustained contraction induced a decline in Mmax with muscle fatigue (3, 35, 45). Therefore, prolonged vibration-induced MVC suppression would not be associated with neuromuscular propagation failure.

Muscle fatigue is characterized not only by a loss of force-generation capacity (20) but also by a slowing of the muscle contractile speed (4, 5). Indeed, previous studies have demonstrated that prolonged passive dynamic or static stretching of plantar flexors, which affects not only Ia afferent functions but also metabolic features in extrafusal muscles (1) and compliance of muscle-tendon units (2, 19), impaired its MVC force (2, 19). Thus, to confirm the effects of prolonged vibration on mechanical and metabolic properties of the muscle or tendon, we investigated the characteristics of twitches before and after prolonged vibration for 30 min. From these reports, it is suggested that prolonged vibration-induced MVC suppression is attributable mainly to the reduction of muscle activity in MG and LG, both of which have a larger proportion of fast-twitch muscle fibers than Sol. This finding suggests that Ia-afferent activity that reinforces the recruitment of high-threshold motor units is necessary to enhance force exertion during MVC.

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