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Anticipatory Changes in the Soleus H Reflex in Humans Related to the Movements of the Contralateral Foot in Upright Stance

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In studies on healthy humans, we examined changes in the H reflex amplitude and the intensity of background EMG (bEMG) of the soleus muscle within the premotor period of voluntary movements of the contralateral foot. In the standing position with support on both lower limbs, we observed facilitation of the tested H reflex and increase in the intensity of bEMG about 60 msec prior to the beginning of conditioned dorsiflexion of the foot. In the case of plantar flexion under analogous conditions, we observed anticipatory inhibition of the H reflex and suppression of bEMG. The pattern of these changes corresponded in general to reciprocal relations between the shin muscles. Opposite results were obtained in the case where the tested persons used an additional hand support. Under such conditions, they leaned only on the tested lower limb, while the conditioning one was not supporting. Plantar flexion of the contralateral foot caused, in this case, anticipatory facilitation of the tested H reflex. Therefore, premotor dynamics of the H reflex and of bEMG of the soleus muscle related to voluntary movements of the contralateral foot depend not only on the kind of movement but also on the body position, absence/presence of additional support, and fulfillment/nonfulfillment of the support function by the lower limbs.

Keywords: H reflex, voluntary movements, anticipatory postural readjustment, contralateral interaction.

INTRODUCTION

Within the premotor period immediately preceding the beginning of different voluntary movements, anticipatory postural readjustments occur. These readjustments are realized due to the action of descending central motor programs and contribute to optimization of the conditions for forthcoming movements. Anticipatory postural readjustments related to the movements of the lower limbs are directed mostly toward the maintenance of body balance. It has been demonstrated that, in a subject standing still and ready for step initiation, certain changes in the tone of skeletal muscles and a shift of the body center of gravity occur within the premotor period [1-4]. Shifts of the muscle tone are also observed in a subject who performs walking limb movements but does not change his/her position [5-7]. The pattern of such shifts depends on the initial position of the tested subject on the support area and on the absence/presence of an additional support.

Recording of H reflex discharges from muscles of the limbs allows one to examine transmission of information in neuronal chains of the spinal cord involved in the control of voluntary movements, as well as the effects of supraspinal structures on segmental reflex mechanisms [8-10]. At different movements of the lower limbs, changes in the H reflex magnitude in the ankle extensor (*m. soleus*) can be observed within the premotor period. Such changes were demonstrated for movements of both ipsilateral [11-15] and contralateral [16] limbs. It was shown that anticipatory shifts in the magnitude of the soleus H reflex related to movements in the contralateral ankle joint are related to alterations of the activity of neuronal systems realizing presynaptic inhibition [17]. Practically all the above-mentioned studies were, however, carried out under conditions where the lower limbs of the tested person were relaxed and fulfilled no supporting function. At the same time, it was found that premotor shifts of the H-reflex values in humans being in upright stance differ significantly from those observed in the lying position [18]. We tried to analyze the physiological mechanisms of the above phenomena and their relation to anticipatory postural readjustments.

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METHODS

Twenty-three volunteers took part in the tests. The H reflex in the *m. soleus* was evoked using a standard technique, namely by transcutaneous stimulation (1-msec-long current pulses) of afferent fibers of the tibial nerve in the region of the popliteal dimple. Using superficial electrodes, we recorded the integral EMG reflex discharge from the *m. soleus*, amplified, and visualized it using a two-channel digital oscillograph, Handiscope HS3 (TieOie Engeneering, the Netherlands). In other tests, we also recorded tonic background EMG activity (bEMG) from the soleus muscle. The intensity of such bEMG was characterized using Origin 8.6 software. After full-wave rectification and low-frequency filtration, we estimated the area under the integral curve enveloping oscillations of the above-mentioned EMG.

We studied the dynamics of the H reflex magnitude and the intensity of bEMG of the soleus muscle within the premotor period during realization of voluntary movements of the contralateral foot. The tested persons were in the standing position with support on both heels or on one heel with an additional hand support. According to a visual light signal (flash of a light-emitting diode), the subject should perform maximally rapidly a conditioning movement in the ankle joint (simple sensorimotor reaction) with an immediate return to the initial position. We studied the effects of two types of movements, dorsiflexion and plantar flexion of the "conditioning" foot. The first EMG oscillations in the corresponding muscles, namely in the *m. tibialis anterior* in the case of dorsiflexion and in the *mm. gastrocnemius+soleus* in the case of plantar foot flexion, served as labels of the beginning of the conditioning movement of the contralateral lower limb.

The tested H reflex was recorded at different time intervals after the light signal to provide complete coverage of the entire latent period of the motor reaction. The values of the recorded H reflexes were normalized with respect to the control ones. The bEMG of the *m. soleus* was also recorded throughout the entire latent period of the test movement. The intensity of such activity was compared with the bEMG intensity prior to presentation of the light signal. Means ± s.e.m. were calculated.

RESULTS

In the first experimental series, we studied the time course of changes of the tested soleus H reflex during the premotor period of dorsiflexion of the contralateral foot. The tested persons were in the standing position with support by both lower limbs on their heels, but without additional hand support. To estimate the dynamics of the examined indices, the premotor period was divided into equal time intervals preceding the beginning of the conditioning movement. At 120- to 90-msec-long intervals before dorsiflexion, the averaged value of the H reflex was 105 ± 7% of the control. At 90-60 msec, this was 103 ± 6%, at 60-30 msec, 145 ± 12%, and at 30-0 msec, 152 ± 10%. Against the background of the initiated movement, the respective value was 141 ± 5%. Thus, facilitation of the H reflex began to develop within the final portion of the premotor period (about 60 msec before the beginning of the conditioning movement).

In the second experimental series with the analogous conditioning movement, we studied the intensity of bEMG recorded from the soleus muscle within the same time intervals of the premotor period. Its normalized indices were the following: 120-90 msec, 114 ± 3%; 90-60 msec, 110 ± 3%; 60-30 msec, 117 ± 7%; 30-0 msec, 150 ± 12%, and against the background of the movement, 174 ± 6%. Results of both above-mentioned experimental series are illustrated by Fig. 1.

In the third and fourth experimental series, using the same approach, we recorded changes in the soleus H reflex and its bEMG preceding another voluntary movement, namely plantar flexion of the contralateral foot. This was possible because the subjects stood on their heels, and they, when

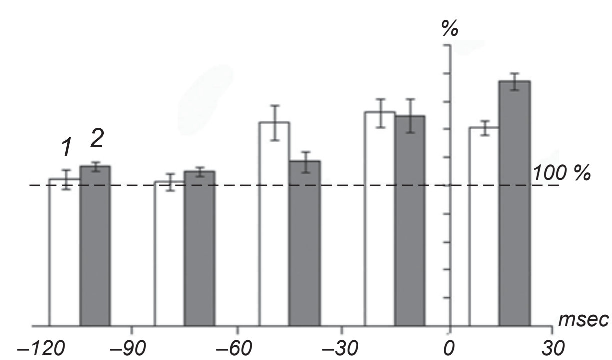

Fig. 1. Dynamics of the magnitude of the soleus H reflex and of the intensity of background EMG recorded from this muscle within the premotor period of voluntary dorsiflexion of the contralateral foot (upright stance with support on both heels). Abscissa) Intervals, msec, with respect to the beginning of EMG activity corresponding to voluntary movements of the contralateral foot; ordinate) averaged normalized value of the soleus H reflex, % (1) and averaged normalized intensity of the background EMG of the soleus muscle, % (2).

performing the conditioning movement, were able to move the foot-pad and toes below the heel level. The results of such experiments are presented in Fig. 2. The obtained data differed significantly from those obtained in the first and second experimental series. Within the 120-90 msec interval prior to the beginning of the movement, the mean normalized value of H reflex in the tested *m. soleus* was 105 ± 3%. At 90-60 msec, it was 68 ± 5%; at 60-30 msec, 53 ± 8%, and at 30-0 msec, 73 ± 11.7%; against the background of the initiated movement it reached 132 ± 12%. Thus, the H reflex during the premotor period was inhibited under the above-mentioned conditions. Inhibition began to develop at about 90 msec prior to the beginning of the conditioned movement, i.e., earlier than facilitation that developed at dorsiflexion. At the end of the premotor period, the depth of inhibition decreased, and it was replaced by facilitation. The dynamics

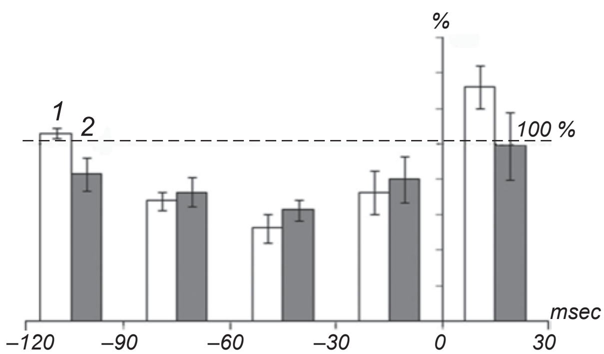

Fig. 2. Dynamics of the magnitude of the soleus H reflex and of the intensity of background EMG within the premotor period of voluntary plantar flexion of the contralateral foot (upright stance with support on both heels). Designations are the same as in Fig. 1.

of the intensity of bEMG recorded from the soleus muscle within the premotor period also differed significantly from those observed under conditions of dorsiflexion of the contralateral foot. Within the interval of 120-90 msec before the movement, the intensity of bEMG was, on average, 83 ± 9%; at 90-60 msec, 73 ± 8%; at 60-30 msec, at 63 ± 6%; 30-0 msec, 80 ± 13%; against the background of the initiated conditioning movement, it corresponded to 99 ± 19%.

In the fifth experimental series, we studied the effect of contralateral plantar flexion under conditions where the tested person used an additional upper limb support by both arms and leaned only on the tested lower limb. The muscles of the limb realizing conditioning plantar flexion

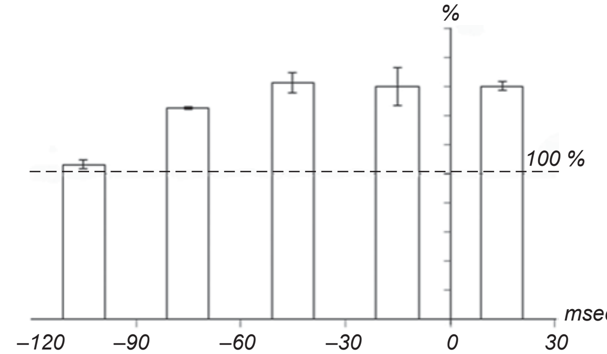

Fig. 3. Dynamics of the magnitude of the soleus H reflex observed at voluntary plantar flexion of the contralateral limb under conditions of the presence of a hand support and no support on the contralateral "conditioning" limb. Abscissa) Intervals, msec, with respect to the beginning of EMG activity corresponding to voluntary movement of the contralateral foot; ordinate) averaged normalized value of the soleus H reflex, %.

were relaxed in the initial state. Figure 3 shows the results obtained in this experimental series. Before the beginning of the conditioning movement, the amplitude of the reflex response of the soleus muscle increased. Within the 120- to 90-msec-long interval prior to beginning of the first conditioning EMG oscillations, the value of the H reflex was 106 ± 3% of the control. Within the 90- to 60-msec-long interval, the amplitude of the test reflex increased to 145 ± 1%/ Within the 60- to 30-msec-long interval, the value of the H reflex was 162 ± 7%, and within time intervals shorter than 30 msec before the beginning of the movement, this value was 160 ± 12%. The value of the soleus H reflex remaining also increased against the background of the voluntary movement of the contralateral limb and corresponded to 160 ± 3% of the control, on average.

DISCUSSION

In the course of our study, we compared anticipatory changes in the magnitude of H reflex discharges recorded from the soleus muscle and bEMG of this muscle during voluntary movements of the contralateral foot. Our tests showed that these indices changed within the premotor period under conditions of upright stance of the tested subject with support on the heels of both limbs, . The direction of these alterations was dissimilar depending on the kind of the conditioning movement. Dorsiflexion of the foot induced anticipatory facilitation of the tested soleus H reflex and increase in the intensity of soleus bEMG, while plantar flexion induced opposite changes in these indices (inhibition of the tested H reflex and also decrease in the bEMG intensity). Thus, reciprocal relations between the lower-limb muscles were reflected in the pattern of such changes. Contraction of the *m. tibialis ant.* providing dorsiflexion of the foot did not result in alteration of the body position of the subject with respect to the support. Plantar flexion of the foot at the expense of contraction of the *mm. gastrocnemius+soleus*, which performs work against the gravitation force, raises the body above the support when the foot-pad and toes move below the heel level. It is natural that the latter group of the muscles (plantar flexors of the foot) is classified as physiological extensors.

With each given conditioning movement of the contralateral foot, the directions of anticipatory (premotor) shifts of the H reflex magnitude and that of bEMG of the soleus muscle were identical. The time course of modulations of the H reflex and bEMG was nearly the same in both preliminary facilitation and inhibition. This circumstance allows us to hypothesize that there is a relation between these phenomena. As is known, the intensity of bEMG reflects the level of tonic activity of motoneurons of the studied muscle. This is why we believe that, in this case, premotor changes of the H reflex can be explained by shifts of the excitability of motoneurons of the soleus muscle under the action of central motor commands. From this aspect, such changes crucially differ from those observed during movements of the contralateral foot under conditions where the lower limbs did not fulfill any supporting function [16, 17]. We obtained evidence that in the latter case such changes are due to processes developing in presynaptic parts of the arcs of the H reflex.

Changes in the H reflex and in bEMG of the soleus muscle observed when the tested subject is in the standing position with support on both limbs can be considered a manifestation of anticipatory postural readjustments. This is confirmed by comparison of these findings and results of the experimental series where the tested subjects used hand support, and the lower limb performing the conditioning movement did not fulfill the supporting function. As is known, an additional hand support results in significant weakening of the anticipatory postural readjustments with the involvement of the lower limb muscles [18]. In the respective experimental series, plantar flexion of the contralateral foot induced anticipatory facilitation of the H reflex analogous to that observed when the tested persons were in the lying position [18]. Therefore, the physiological importance and the mechanism of premotor changes in the H reflex in the case of movements of the contralateral limb are determined not only by the kind of these movements; these changes depend, to a significant extent, on the conditions under which these movements are realized.

The tests were carried out in agreement with internationally accepted ethical norms for scientific research with the involvement of humans. All subjects were volunteers and gave their written informed consent for their participation in the tests.

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