Modulation of the ipsilateral and contralateral H reflexes following ipsilateral mechanical pressure of the foot in normal subjects

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Abstract
The modulation of the soleus H-reflex in response to tonic mechanical pressure applied to the plantar aspect of foot sole was examined in 16 normal subjects. Tonic mechanical pressure applied to the medial and lateral regions of the ipsilateral foot sole significantly depressed soleus H-reflex excitability in ipsilateral and contralateral feet in all subjects. The demonstration of a decrease in H-reflex excitability as a result of applied pressure to the foot sole suggests that the change in reflex excitability is the result of a common spinal mechanism. These evidences highlight the modulatory effects that natural stimuli might have on reflex excitability. These evidences might also have practical application in the management of disorders of muscle tone particularly in physical therapy and rehabilitation medicine.

Keywords: soleus H-reflex, mechanical pressure, medial and plantar nerves,

I. Introduction
Mechanoreceptors from the foot sole are likely to play a role in the reflex regulation of muscle tone and control of motor patterns. They may also provide important sources of phasic sensory feedbacks following damage to one or more components of the brain or nerve pathways. (7, 18) Mechanoreceptors usually transform a continuously varying mechanical stimulus into trains of action potentials. (17, 21) Somatosensory inputs from the lower limb have been recognised as important sources of sensory information (19). Our knowledge of skin inputs from the foot sole are largely based on indirect evidences (22). On the other hand, microneurographic recordings from the peripheral nerves have provided direct analysis of the functional properties of skin receptors in response to various stimuli. The integration of all these somatosensory inputs appears to provide important information about the body’s position with respect to supporting surface. (18) Collectively, considerable evidences therefore suggest that feedback from the foot sole can influence spinal reflex pathways in normal and SCI subjects. Based on assessments of multi-units activities of the mechanoreceptors in the foot sole, the activities were evoked predominantly in the medial or lateral aspects of the foot, corresponding to the medial and lateral plantar nerves divisions in the tibial nerve. (4, 12, 21) Accordingly, the main purpose of this study was to investigate the most effective region under which to apply the mechanical pressure to inhibit excitability of the soleus motorneuron pool.

The H-reflex has been used as an indirect measurement of alpha motorneuron excitability. It was hypothesised that repetitive low threshold afferent stimulations would have inhibitory
effects on the triceps surae H-reflexes. (11, 6, 16)

II. Materials and Methods
Sixteen volunteers without any orthopedic or neurological problems, (5 men and 11 women) aged between 20-30 yrs. (25.5±2.07) participated in this study. They were each informed of the purpose and method of study and provided written consents. Approval of the study was obtained from the ethical committee of Tehran University. Each subject completed a questionnaire to ensure that they were both healthy and not taking any medications that could affect the activity of the central nervous system.

Reflex testing
All tests were conducted with the subjects lying prone (knee angle 15°-20° and ankle angle 10° plantar flexion) with both feet strapped to the bed. The H-reflex and M-responses of the soleus muscle were elicited according to the classic protocol of Hugon (2, 14).

To evoke direct M-wave and H-reflex in the left soleus muscle, the left tibial nerve was stimulated precutaneously using an electrical stimulator. Ag-Agcl bipolar stimulus electrodes were attached bilaterally to the skin over the tibial nerve in the popliteal fossa with an interelectrode distance of 2.5 cm. The tibial nerve was stimulated by a rectangular current pulse of 1 m.sec duration (15, 13). The intensity of the stimulation was gradually increased to record maximal H-reflex, followed by M-response. A cuff-type ground electrode was placed between the stimulating cathode and the recording electrodes. Ag-Agcl recording electrodes were attached bilaterally to the skin over the belly of the soleus muscle with an interelectrode distance of 3 cm.

Electromyographic signals were obtained from both (RT & Lt) soleus muscles. The signals were amplified and filtered (5Hz to 5 KHz, Toennies Neuroscreen), and were stored for further analysis.

The amplitude of evoked M-wave was continually monitored during the course of study for assessing the stability of stimulation and recording conditions (22). In addition, a flat platform (3×3 cm) was designed and alternatively positioned in the medial and lateral plantar arches (foot sole) for application of mechanical pressures.

III. Cutaneous Mechanical Pressure
As mentioned above, a platform was positioned in the medial and lateral plantar surfaces of the foot for application of mechanical pressures (was applied for 15 minutes continuously). The position of the platform could be manually raised or lowered with respect to the surface of the foot sole, thereby altering the region of the applied pressures to the medial or lateral sole of dominant foot. (fig.1, 11). The amount of applied pressure was determined according to the anthropometry table (i.e. 50% of foot and leg weight) and was exerted by the platform to the foot. The pressure was measured by dynamometer (medical research) that was incorporated into the platform design.

After Application of Mechanical pressure
After an initial delay, about 5 minutes to allow the force acting on the foot, a further H-reflex of highest amplitude was evoked and the recorded size of the M-wave and H-reflexes were monitored. If significant differences between the size of M-wave in control and experimental data sets were identified, the H-reflex data were discarded and the test repeated. Parameters of H-reflex and direct M-wave responses were measured (peak-to-peak amplitudes, latency) every 5 minutes in 15 minutes of test duration and 5 minutes after cessation of applied mechanical pressure. The
H/M ratio was estimated for each experimental condition.

IV. Results
Paired T-test was used for comparisons of the H/M ratio, and H-reflex latencies (SPSS for windows). A significant of P≤0.05 was used for all comparisons.

The effects of mechanical pressure (loads on the medial and lateral plantar surfaces of the foot sole) on the size of H-reflexes were shown in figure 2. In both conditions, the amplitudes of the ipsilateral and contralateral H-reflexes were reduced when compared with the control. The reduction in the size of H-reflex occurred without any changes in M-wave characteristics demonstrating that the stimuli conditions have not altered.

The depressions of the sizes of H-reflexes were observed in all subjects. The differences between the mean sizes of the control and the conditioned reflexes were significant (P≤ 0.05).

During the application of lat-plantar pressure, the size of H-reflex was reduced about 42.4 % (± 9.34) of control value, whilst in the medial plantar pressure; the reflex was reduced about 27.2% (± 4.73) of control value (figure 2).

The H/M ratio following application of the lateral and medial plantar pressures were shown in figures 3 & 4; it is apparent that the ratios were reduced 38.40%±11.54 and 22.69±13.5% respectively.

V. Discussion
In this study, the modulations of H-reflexes were studied in 16 healthy subjects following application of mechanical pressures on the medial and lateral aspects of the foot. The group ensemble average H-Amplitude activation pattern recorded in this study was similar to that reported by other authors (Conway BA, knikou M, 2001 Hiraoka K 2003, Wood L 1998). The main aim of the study was to determine the effect of mechanical pressures on motoneuronal excitabilities. The results of this study showed that the amplitude of H-reflexes and H/M ratio decreased almost linearly across the time intervals of applied pressure.

The change in peak amplitude was found to be statically significant (p<0.05). It might be therefore concluded that the change in peak amplitude and the increase of H-reflex latency was due to the mechanical pressure.

Pressure applied to the foot sole might activate many types of cutaneous mechanoreceptors resulting in widespread and mixed oligosynaptic actions. (8,19) However, it is interesting to note that while localized brushing of the skin overlying the soleus muscle can reduce H-reflex excitability (3,1), similar stimulation of the foot sole results in a decrease in presynaptic inhibition of soleus Ia afferents.(14,12). Thus it is likely that the superficial cutaneous receptors activated by brushing the foot sole did not contribute to the present findings (8). Accordingly, the slowly adapting subcutaneous mechanoreceptors might contribute to the inhibition of soleus H-reflex in this study. A depression of the size of soleus H-reflex in standing position has been reported by Hyashi et.al (in comparison to that observed in sitting position) 10. Although the current data should be interpreted cautiously with respect to standing, it is probable that some of this reduction could be attributed to afferent feedback from the foot (5, 1). Similarly, load related afferent feedback might also be considered as an important mechanism that could influence the pattern of muscle activity during walking. In this study, we applied tonic pressure to the skin overlying the medial and lateral plantar region of the foot sole. (4) The demonstration that pressure applied directly to the foot sole (in normal subjects ,in sitting position) could powerfully inhibit the soleus H-reflex supports the hypothesis that feedback...
from load sensitive receptors in the foot sole may contribute to the regulation of the human muscular tone. The adequate stimulation of these afferents might therefore be useful in locomotor training in SCI subjects. These evidences might be interesting for researchers who are involved in the reflex induced extensor hypertonicity. (13, 17)

The decrease might be mediated by the afferent nerve fibers of the lateral plantar nerve (a branch of the tibial nerve) because this nerve mediates sensation of the lateral region of the foot sole. (20) Neurophysiologic studies have reported that electrical stimulation of the tibial nerve at the ankle inhibits excitability of the soleus muscle at a latency of 50 msec or beginning at 45-50 msec in stance position. In addition, the stimulus has also inhibited the motoneuronal excitability in the soleus muscle during the late stance phase of gait. Thus, the reason why a significant decrease was not observed in applying pressure to the medial plantar foot sole might be due to the differences in connections of the afferent nerve fibers to the soleus motoneuron pool between the lateral and medial plantar nerves. (3, 13)

Two types of receptors might be related to our findings: Proprioceptive receptors in the intrinsic muscles and cutaneous receptors in the sole of the foot (21, 9). A small plate to apply pressure to the plantar eminences should tonically press the skin under the plate, thus increasing cutaneous afferent discharge. Many inhibitory pathways presynaptically converge to the soleus motoneuron pool. However, the cutaneous afferent discharge decreases the excitability of the presynaptic pathway. Thus if we consider that cutaneous afferent discharge can inhibit the motoneuron pool, the mechanism might be something other than enhancement of the presynaptic pathway (21, 11) Rather, the decrease might be related to the mechanical stimulation of muscle spindles in the intrinsic muscles that attach to or pass through the fifth metatarsal head. (15, 18) A small plate placed under the lateral plantar eminence should stretch the intrinsic muscles. If mechanical stretching of the intrinsic muscle is what inhibits the motoneuron pool, the enhancement of presynaptic pathway might have some primary role in this regard.

The clinical implication of the current findings is that the placement of a small, flat plate in order to apply pressure to the lateral plantar eminence might be useful for regulating the tonicity. This might be useful in the management of spasticity, because spasticity is at least partially caused by hyperexcitability of the motoneuron pool (12, 8, and 15). Further studies on subjects with spasticity are needed to prove this assumption because the findings of the present study were only derived from neurologically intact subjects.

![Fig. 1. The device for applying mechanical stimulation](image1)

![Fig. 2. The average H-reflex recorded after medial (a) and lateral (b) mechanical stimulations (before: dashed line; after: solid line) in a normal subject. Note that the reduction of H-reflex amplitude in the loaded condition](image2)
for subjects occurred without significant changes in M-wave.

Fig 3. The effect of applied tonic medial pressure to the foot sole on the magnitude of the soleus H-reflex Amplitude.

Fig 4. The effect of applied lateral tonic pressure to the foot sole on the magnitude of the soleus H-reflex Amplitude.

References:


