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Original article

Patellar tendon vibration reduces the increased facilitation from quadriceps to soleus in post-stroke hemiparetic individuals

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ABSTRACT

Background: Stimulation of the femoral nerve in healthy people can facilitate soleus H-reflex and electromyography (EMG) activity. In stroke patients, such facilitation of transmission in spinal pathways linking the quadriceps and soleus muscles is enhanced and related to co-activation of knee and ankle extensors while sitting and walking. Soleus H-reflex facilitation can be depressed by vibration of the quadriceps in healthy people, but the effects of such vibration have never been studied on the abnormal soleus facilitation observed in people after stroke.
Objectives: To determine whether vibration of the quadriceps can modify the enhanced heteronymous facilitation of the soleus muscle observed in people with spastic stroke after femoral nerve stimulation and compare post-vibration effects on soleus facilitation in control and stroke individuals.
Methods: Modulation of voluntary soleus EMG activity induced by femoral nerve stimulation (2 × motor threshold) was assessed before, during and after vibration of the patellar tendon in 10 healthy controls and 17 stroke participants.
Results: Voluntary soleus EMG activity was facilitated by femoral nerve stimulation in 4/10 (40%) controls and 11/17 (65%) stroke participants. The level of facilitation was greater in the stroke than control group. Vibration significantly reduced early heteronymous facilitation in both groups (50% of pre-vibration values). However, the delay in recovery of soleus facilitation after vibration was shorter for the stroke than control group. The control condition with the vibrator turned off had no effect on the modulation.
Conclusions: Patellar tendon vibration can reduce the facilitation between knee and ankle extensors, which suggests effective presynaptic inhibition but decreased post-activation depression in the lower limb of people after chronic hemiparetic stroke. Further studies are warranted to determine whether such vibration could be used to reduce the abnormal extension synergy of knee and ankle extensors in people after hemiparetic stroke.

1. Introduction

After stroke, muscles of the lower limbs often show pathological synergy [1]. The impairment is characterized by co-activation of the extensor muscles that produces abnormal coupling during active movements. For example, after hemiparetic stroke, during gait, activation of the quadriceps (Quads) in early stance is often accompanied by premature activation of ankle extensor muscles [2–4].

The spinal mechanisms involved in sensorimotor impairments after stroke are still unclear. Changes in inhibitory pathways that modulate the postsynaptic activity of motor neurons at similar or adjacent segmental levels (i.e., spinal levels) have been associated with motor deficits after stroke. At segmental levels, deficits in reciprocal inhibition have been related to changes in muscle tone in the paretic arm [5] and to hyperreflexia in the paretic leg [6], whereas the reestablishment of reciprocal inhibition follows the motor recovery of the leg [7]. The impaired recurrent inhibition has been related to spasticity in some individuals [8].

Changes in the transmission of intersegmental pathways that influence motor neuron activity at different segmental levels could also contribute to motor impairments of the paretic leg. Some

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investigations of people with hemiparetic stroke have shown an abnormal increase in intersegmental facilitation of the Quads by excitatory influences from non-monosynaptic group I and II afferents projecting from the common peroneal nerve to the Quads [9,10]. Also, such people show altered oligosynaptic intersegmental pathways because of abnormally enhanced facilitation of the soleus (Sol) H-reflex and voluntary activity by excitatory afferents from the Quads and lack of the later heteronymous inhibition [11,12]. Furthermore, this increased heteronymous facilitation has been related to incoordination and motor recovery of the paretic leg [11]. It is also associated with the amount of coactivation of the ankle extensors during static knee extension while sitting [12] and walking [4].

Heteronymous facilitation from the Quads to the Sol was studied to assess changes in presynaptic inhibition (PI) of Ia afferents [13], but PI was claimed to be normal in the paretic leg [13]. However, assessing PI with other methods has led to contradictory results: PI was found reduced [7] or normal [13,14] in the paretic leg and reduced with chronic hemiparesis [15] when assessed by vibration-induced depression of the Sol H-reflex [16,17].

Muscle vibration induces inhibition of the phasic reflexes (stretch and H-reflexes) of the homologous muscle in humans [18–21]. A PI mechanism and a post-activation depression (PAD) mechanism may be involved in such vibration-induced inhibition [22,23]. Fig. 1 shows a schematic representation of the heteronymous pathway by which Ia afferents from Quads can facilitate Sol motor neuron activity. Vibration of the Quads, which strongly stimulates Ia afferents, could decrease this excitatory influence by increasing PI and/or PAD.

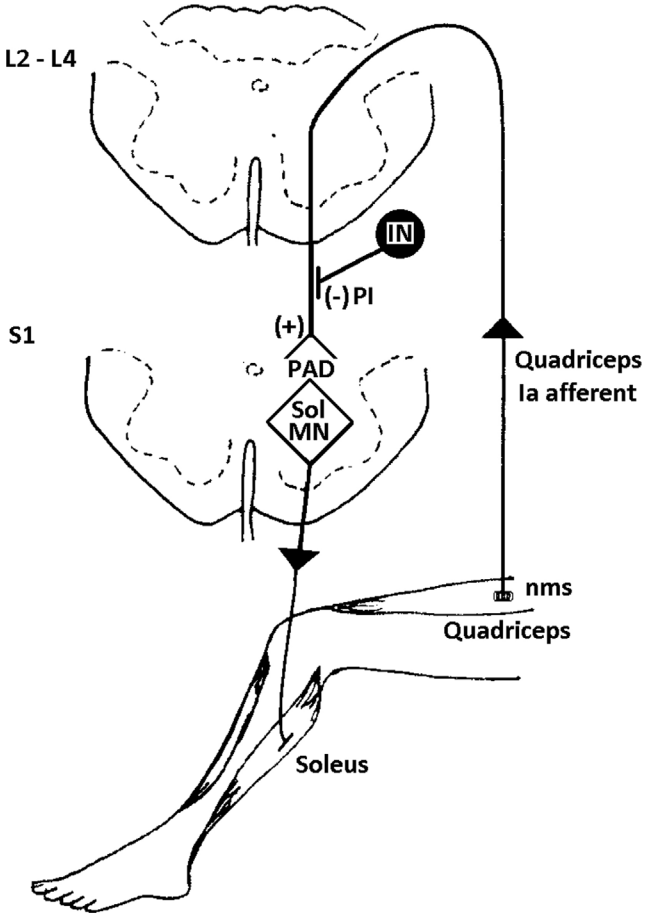

Fig. 1. Modulation of heteronymous Ia afferents from quadriceps to soleus motor neurons. Stimulation of the quadriceps neuromuscular spindles (nms) activates both homonymous and heteronymous Ia afferents, which excite soleus motor neurons (Sol MN). This excitation may be modulated by presynaptic inhibition (PI) coming from interneurons (IN) or by post-activation depression (PAD).

Changes to the PAD mechanism might help alter vibration-induced inhibition of the phasic reflexes of muscles after stroke [22,23]. In fact, the level of PAD was found related to the severity of spasticity in stroke patients [24] and reduced in individuals with multiple sclerosis [25], spinal cord injury [26] and stroke [14,27,28]. Conversely, individuals with stroke showed normal PI of intersegmental monosynaptic excitation by Ia afferents from the Quads to Sol [13]. Thus, the increased heteronymous facilitation of Sol activity by Quads afferents observed in stroke individuals [12] might result, at least in part, from a decrease in PAD. Such an effect has been explored in the transmission of intersegmental monosynaptic facilitation of Sol H-reflex activity by Quads afferents in healthy individuals [29]. The vibration of Quads (but not of Sol) can depress the early heteronymous facilitation of Sol H-reflexes by stimulating the femoral nerve [29]. The question then arises as to whether vibration-induced depression can modulate the increased heteronymous facilitation of Sol after stroke. Vibration of the Quads could theoretically induce depression of heteronymous facilitation via the effect of PI in both control and stroke individuals. Nevertheless, post-vibration effects would be less significant in stroke than healthy individuals with the reduced PAD in the paretic leg.

The objectives of this study were to:

- determine whether vibration of the Quads could modify the heteronymous facilitation of voluntary Sol activity in healthy controls and stroke individuals;
- compare post-vibration depression effects on Sol facilitation between control and stroke individuals.

2. Methods

2.1. Participants

Stroke participants (age range 24 to 72 years) with chronic hemiparesis included had the following criteria: a single cerebrovascular accident involving the motor cortex, internal capsule or sub-cortical areas, as documented by brain imagery, that resulted in motor deficits of abrupt onset affecting the controlateral lower limb. Healthy volunteer controls included were between 18 and 65 years old with no history of neurological disorders. All participants were able to produce voluntary, sustained plantar flexion contractions to perform the experimental task, which consisted of pressing a fixed platform with the forefoot. Stroke participants were excluded if they were taking antispastic, anxiolytic or antidepressant medication at the time of the study and if they had receptive aphasia, hemispatial neglect or a passive range-of-motion limitation of the paretic leg that could interfere with the experimental positioning. Participants with stimulators (e.g., a pacemaker) or metallic implants were excluded, as were those with orthopaedic or neurologic disorders other than stroke. All participants gave their written informed consent. The study was approved by the internal ethics committee for *Centre de recherche interdisciplinaire en réadaptation* (CRIR) institutions.

2.2. Clinical assessments

Before the experimental session, stroke participants were evaluated in terms of their level of motor recovery, degree of spasticity and level of coordination of the paretic leg by using the Chedoke-McMaster Stroke Assessment (CMSA) subscales for motor recovery stage for the paretic leg (CMSA Leg) and for the foot (CMSA Foot) [30]. They were also assessed by using the Composite

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