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Comparison of tap-evoked and tone-evoked postural reflexes in humans

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Abstract

To find an easy clinical test of postural reflexes, we compared tone and tap stimuli for eliciting postural reactions in leg muscles in 13 healthy subjects during upright stance. Tones (1000 Hz, 90 dB nHl) were presented monaurally via headphones; taps were applied with a reflex hammer to the forehead. Surface EMG was recorded from the medial gastrocnemius and the sternocleidomastoid muscles, and rectified and averaged. Tapping the forehead of a standing subject evoked leg muscle reflexes that began 50 ms after the stimulus in all subjects. Tone-evoked leg muscle reflexes behaved differently, i.e., they had smaller amplitudes and could be recorded in only 5 of 13 subjects. However, this same acoustic stimulus elicited reflex activity in the neck muscles of all subjects. There were also other differences (amplitudes, dependence on pre-activation) between these two reflexes. Tone-evoked leg muscle responses and tone-evoked neck muscle responses seem to be mediated by different structures, i.e., the latter by an oligosynaptic pathway and the former by polysynaptic neural circuits. We conclude that tap-evoked leg muscle responses are not or not solely mediated by saccular receptors but other receptors (i.e., proprioceptors, semicircular canals) are probably also involved.

Keywords: Human posture; Postural reflexes; Vestibulospinal pathways

1. Introduction

The equilibrium of a standing person is maintained by highly automated sensorimotor programs that involve vestibular, visual, and proprioceptive postural reflexes. The influence of these sensory modalities on the equilibrium is modulated according to the actual postural task [1], presumably by means of a neural circuit that extends from the spinal cord to the brainstem and also involves the cerebellum. The assessment of patients with postural and gait disorders is therefore not limited to only tests of sensory functions and elementary single modality reflexes, such as the vestibulo-ocular reflex and deep tendon reflexes. The use of posturography combined with tilt-table tests, which cause perturbations that initiate multisensory postural responses, may be necessary [2,3]. Other dynamic methods to elicit short-latency leg muscle activation in standing subjects are sudden head displacements [4] and neck muscle vibration [5]. Additional ways to elicit leg muscle reactions are transmastoidal galvanic vestibular stimulation or loud clicks. The effect of galvanic stimulation on leg muscles is modulated by head rotation and the presence or absence of other cues that might be used to make postural adjustments [6–8]. Thus, these reflexes are mediated by a complex circuit involving several afferents. This is probably also true for click stimuli, which are capable of eliciting leg muscle responses [9]. Acoustic stimuli in the form of loud clicks or tones are capable of exciting saccular receptors [10]. Clicks and tones consistently evoke reflexes in the pre-activated *neck* muscles, and therefore these stimuli have been increasingly used as a test for vestibular function [11–14]. Leg muscle reflexes evoked by acoustic stimuli seem to be inconsistent, since they could not be observed in all normal subjects [9,15] and they are systematically influenced by head position [16]. In pathological conditions in which the transduction of sound to

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the vestibular apparatus is abnormal (Tullio phenomenon), these leg muscle reactions are increased [17].

Finally, tapping the forehead of a standing subject with a reflex hammer also elicits leg muscle responses [18]. This method is similar to that for tap-evoked neck muscle reflexes [19]. When the subject leans backward, a forehead tap activates the anterior tibial muscles after a latency of 42 ms. Conversely, when the subject leans forward, a tap briefly inhibits the gastrocnemius muscles. These postural reflexes are probably not a direct response to the vestibular stimulus, since a tap on the sternum causes the head to move in the opposite direction, but evokes the same responses [18]. It was, therefore, assumed that proprioception, i.e., mainly neck muscle spindle receptors, may be essential for these postural reflexes. Neck muscle receptors have connections to vestibular nuclei [20].

To establish normal values, we compared the results of tone-evoked and tap-evoked leg muscle activation and established the role of the level of muscular pre-activation. Furthermore, the tone-evoked vestibulocollic reflex was compared with the tone-evoked leg muscle responses to assess factors that might contribute to the variability of the tone-evoked leg muscle responses.

2. Methods

Thirteen healthy volunteers (mean age 32 years, range 25–38; 7 males, 6 females) participated in the study. The experimental procedures were approved by the local ethics committee. Subjects were examined under three conditions: one involving forehead taps and two involving tones presented to the right ear but with the head in different positions. In all tests, the subject stood upright with eyes closed and leaned slightly forward (thus pre-activating the gastrocnemius muscles, which were monitored on line).

2.1. Stimulation

The stimulus of the first test consisted of slight taps to the forehead (3 cm above the nasion, anterior–posterior direction) with a specially designed aluminum hammer weighing 0.25 kg. Its tip consisted of a rubber eraser (thickness 7 mm, area 2 cm^2) to soften the impact. A pressure-sensitive foil between the rubber and the hammer was connected to an electronic circuit, which caused a trigger impulse with a delay of 1.5 ms after the start of the impact. The hammer was always manually operated by the same person. The signal of the foil was displayed on an oscilloscope screen and the intensity of the taps was adjusted to cause a constant signal in all subjects. The tap caused the head to move backward approximately 2–3 mm (Fig. 1, right column). Taps were delivered at irregular intervals (2–4 s). Sixty taps were applied in one test; each test was repeated once.

In the two other conditions, tones were applied to the right ear. The characteristics of the tone were 1000 Hz, 90 dB nHl, 4 ms duration including 1 ms rise time and 1 ms fall time. In pilot experiments comparing click, and 500 and 1000 Hz stimuli, the stimulus finally used yielded the largest amplitudes. The stimulus was delivered through calibrated headphones (Beyer dynamic, DT48). The subject's head was turned actively as far as possible either to the left (condition tone right, head left) or to the right (condition tone right, head right). Tones were repeated 120 times in one test, each after an irregular interval lasting 0.8–1.5 s. Each test was repeated once.

2.2. Recordings

Monopolar surface electromyography (EMG) recordings were made from the sternocleidomastoid (electrode: midpoint of the muscle; reference electrode: sternum) and gastrocnemius muscles (reference electrode: patella) bilaterally, using silver cup electrodes filled with electrode gel.

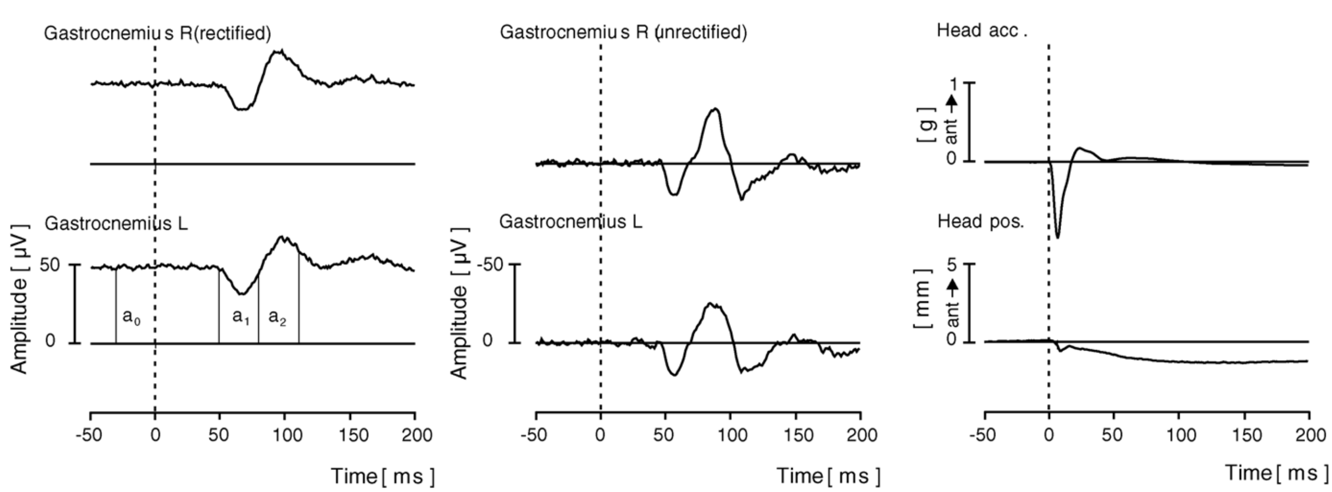

Fig. 1. Tap-evoked leg muscle responses, averaged data from 13 subjects. Data on the left were rectified before averaging. The epochs for which integrals were computed are denoted with a_0, a_1, and a_2. Middle: unrectified data. Right: head acceleration and positional change caused by the tap. Vertical line indicates the time of head tap.