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Measurement of Plantar Sole Sensitivity: A Tool for the Podiatric Diagnosis

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Editorial

Measurement of plantar sole sensitivity could be useful to the podiatrists who have to diagnose patients at risk of diabetic neuropathy. The plantar surface is the major weight bearing surface during gait and standing. The cutaneous mechanoreceptors of the plantar sole detect the application of load. An electrophysiological study in humans [1] reported the presence of both slow (Merkel and Ruffini corpuscles) and fast (Meissner and Pacinian corpuscles) adapting receptors in the foot sole, with far greater numbers of the latter (71% of tested units). Skin mechanoreceptors were classified into four groups based on their afferent firing properties [fast adapting (FA) vs. slow adapting (SA)] and receptive field size [type I (small defined boundaries), vs. type II (large undefined boundaries)]. Johansson et al. [2] found that SAI and SAII skin afferents were activated by low vibration frequencies between 2 and 32 Hz whereas FAI were activated between 8 and 64 Hz and FAII between 64 and 400 Hz.

There are several studies indicating that plantar cutaneous mechanoreceptors contribute to controlling the standing balance and postural reflexes in healthy subjects [3-6]. Indeed, balance problems are often related to cases where a reduced plantar sensitivity occurs. Electrophysiological studies have shown that the cutaneous afferents from the plantar surface project on the somatosensory cortex leading to a perceptual representation [7]. Examination of the vibration sense is widely used as a clinical examination in neurology and it is usually done at the medial or lateral malleolus. Most of studies only measured the vibration detection threshold of the sole in healthy subjects in an attempt to compare normal values to those measured in aged individuals and diabetic patients [8-13]. On the other hand, very few data are found on the magnitude of the vibration estimate of the foot sole in response to the increased amplitude of the vibratory stimulus. To determine the estimate of vibrations delivered to the skin of the hand, Verillo et al. [14] already used a psychophysical approach giving the global gain of the sensory detection. We already used this method to determine the sensory detection of tactile stimulation applied on the fingers [15] or the plantar sole [16]. More recently, the global gain of vibration detection by the plantar sole was determined in young and old healthy subjects [17]. The Stevens power function brings a psychophysical approach of the relationship between the estimate (Ψ) of stimuli applied on the foot sole and its physical magnitude (Φ) ($\Psi = k^{*}\Phi^{n}$). The exponent n in the power law was determined by a linear regression analysis between Napierian logarithmic (Ln) transformed stimuli and estimation data. Any increase in k value indicates an elevated sensitivity to the lowest loads and thus a lowered detection threshold. The n coefficient measures the changes in perception between the extreme values of loads. Thus, the n coefficient measures the gain in perception and k gives an approach of the threshold for perception. To test tactile perception of the foot sole [16], the participant layed flat on a bed. Mechanical stimuli were randomly applied to the heel or metatarsal area using a bespoke electronic stimulator device. The stimulator delivered rectangular pulses of 100 ms duration which drove a mechanical probe via a solenoid. Four mechanical stimuli (24, 41, 69 and 116 g) were delivered in random order, producing local plantar pressures of 3.4, 5.7, 9.7, and 16.3 $N.cm^{-2}$. To test vibration perception of the foot sole [17], the participants sat comfortably. The skin sensitivity was evaluated using vibration testing at three frequencies (25, 50, and 150 Hz) at each one of three foot plantar locations (hallux, fifth metatarsal head, and heel). The vibration frequencies were chosen to target the activation of three different skin receptors in the glabrous skin of the foot (25 Hz for SAI, 50 Hz for FAI, and 150 Hz for FAII) based on data obtained by Johansson et al. [2]. Vibrations were applied to the foot sole by a minishaker and a preload force of 2N was measured with a force transducer. The vibrator device allowed delivering different amplitudes of vertical motions of the probe. The vibration magnitude depended on its frequency and varied in a range of 10 to 360 µm at 25 Hz, 10 to 330 µm at 50 Hz, and 10 to 180 µm at 150 Hz. The bespoke apparatus built to deliver tactile or vibratory stimulus are

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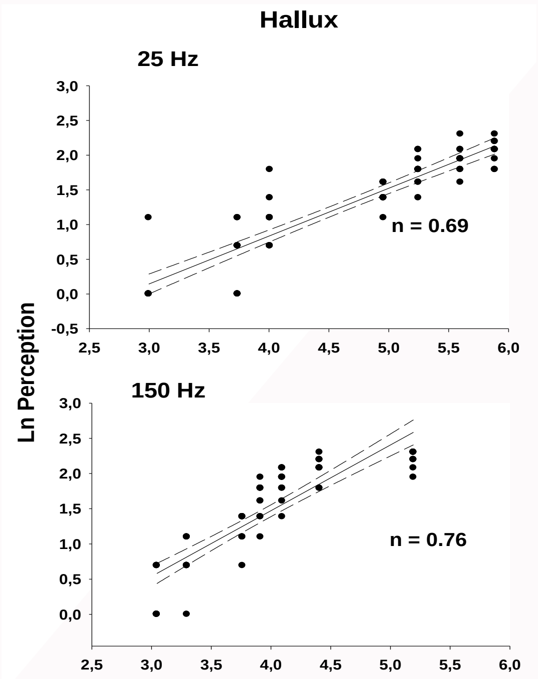

Figure 1: Graphical representation of the relationships between perception and vibration amplitude tested at two vibration frequencies. The n coefficient which measures the gain of sensation is significantly higher at the highest vibration frequency which activates the fast adapting sensory endings.

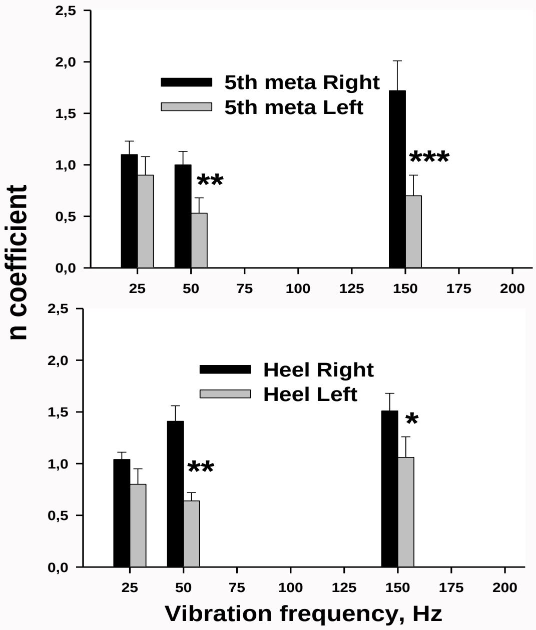

Figure 2: Altered vibration sensitivity in a 66 yr old male patient who related posterior pinch disc of the 3rd to the 5th lumbar metamere assessed by X ray images, leading to an alteration of clinical sensitivity on the course of the left external popliteal nerve.

fully described and shown in our previous studies [16,17]. Judgments of increased stimuli intensity were recorded on a 0-10 cm visual analogue scale. The whole duration of the two trials to explore the tactile and vibratory sensitivities was 10 min. We prefer to explore the vibration sensitivity than the tactile one. Indeed, vibration testing allows examining different skin mechanoreceptors including the fast adapting ones. Besides, the tactile stimulation allows to only exploring the slow adapting sensory units. Figure 1 gives an example of linear regressions obtained between the vibration amplitude and its perception at two frequencies (25 and 150 Hz). The gain of perception was always higher with the 150 Hz vibration frequency which activated the fast adapting units. Compared to the young adults, the elderly had lower n values measured at this high frequency.

Figure 2 shows an example of clinical use of plantar vibration sensitivity to assess an altered sensitivity in a patient with a reduced clinical sensitivity on the course of the left external popliteal nerve.

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