Ronnie Lundström

Neurological diagnosis – aspects of quantitative sensory testing methodology in relation to hand-arm vibration syndrome

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Abstract Objective: The objectives are to summarise the fundamental neurophysiological base for quantitative sensory testing (QST), and to discuss associated methodological and practical aspects necessary to consider with respect to applicability and reliability as a screening or diagnostic aid for vibration-induced sensory neuropathy. Results: QST is the use of psychophysical techniques to measure the intensity of stimuli needed to produce specific sensory perceptions. The physical components are graded stimuli presented to the skin, eye or ear. The psychological component is mental recognition of the physical stimulus. Sensory modalities are named after the subjective feelings elicited, i.e. touch, pressure, vibration, warmth, cold and thermal pain. Since an exposure to vibration may cause symptoms and signs of sensory neuropathy in the hand and arm, the use of QST as an aid for screening and diagnosis has gained an increasing interest. The “Stockholm Workshop” classification scale for sensorineural stages also requires QST. Further, QST has also spread into many other areas, such as in the screening and diagnosis of peripheral neuropathy or polyneuropathy induced by different types of illness, exposure to toxic substances, compression and nerve entrapment. Conclusion: QST is in general easy to perform, usually not associated with pain (except thermal pain), suitable for screening and can readily be conducted in the field. QST is, however, known to be susceptible to the effects of multiple covariates and test methodologies. It is thus important that the relative influence on test results from all significant covariates are identified, and to standardise test methodology accordingly before QST can become a reliable and useful tool for diagnostic and screening purposes in the field of vibration-induced sensory neuropathy. The sensitivity, specificity and reliability of different methods for QST for this type of disorder is still very much unknown. Lack of normative values, standardisation of methods and of a “gold standard” for the presence of sensory neuropathy are some reasons.

Keywords Perception · Psychophysics · QST · Tactile · Thermal · Vibration

Introduction

Recognition that sensory neuropathy may occur independently of the episodic vasospasms characteristic of hand-arm vibration syndrome (HAVS) has entailed an increasing interest in quantitative sensory testing (QST) for screening and diagnosis of vibration-induced neuropathy [24, 40, 76]. In addition, the internationally agreed use of the Stockholm Workshop classification scale regarding sensorineural stages of HAVS also requires the use of QST [3]. QST has also gained application in many other areas, such as in the screening and diagnosis of peripheral neuropathy or polyneuropathy induced by different types of illness (e.g. infections, metabolic disturbances, endocrinological diseases, diabetes mellitus) or exposure to toxic substances (e.g. acryl amide, cyanide, solvents, pharmaceutical preparations) and compression (e.g. carpal tunnel syndrome (CTS), nerve entrapment) (for a review, see e.g. [113]. QST can be defined as the use of psychophysical methods for measurement and quantification of abnormalities with respect to different modalities of sensation. The physical components are graded stimuli presented to the skin, eye or ear. The psychological component is mental recognition of the physical stimulus. Suitable cutaneous sensation modalities for QST are touch, pressure, vibration, warmth, cold and thermal pain. QST, which


R. Lundström
National Institute for Working Life,
Technical Risk Factors, P.O. Box 7654,
907 13, Umeå, Sweden
E-mail: Ronnie.Lundstrom@niwl.se
Tel.: +46-90-176024
Fax: +46-90-176116
is typically used for the determination of sensory detection thresholds (i.e. the smallest difference that can be detected at 50% of the time) or other sensory responses from suprathreshold stimulation (e.g. just noticeable differences or hypersensitivity), allows for a non-invasive quantitative functional assessment of the complete sensory neural axis, i.e. from sensory receptor to cortex. This is an advantage compared with, for instance, electrophysiological measurements such as sensory and motor nerve conduction velocities, which only sample the peripheral nervous system [113]. The concept of QST has a history of more than 100 years. For instance, in 1896 von Frey developed a tool for quantitative measurements of pressure thresholds, i.e. the von Frey hairs [105]. Since then, many different methods and techniques for QST have been proposed, developed, tested and evaluated for the different modalities of sensation (for an overview, see e.g. [9, 26, 109, 113]).

QST is, in general, quite easy to perform, usually not associated with pain (except thermal pain), suitable for screening, and can readily be conducted in the field. However, QST has also been questioned and criticised. Common objections are that the various methods used for QST are not standardised or validated and that there is a large amount of inter- and intra-individual variability in test results. It has also been pointed out that the sensitivity, specificity and reliability of QST is still very much unknown. Another drawback with QST is that it seems to be impeded by the lack of agreement on which stimuli, testing procedure and criteria for response levels should be recommended for clinical or research purposes. Furthermore, since QST is based on subjective responses it demands full co-operation and concentration from the test person. The question of whether limitations of QST exist when test persons are biased towards a bad outcome has also been raised [31], e.g. in a worker’s compensation case. It should be noted, however, that the reverse may also be true, for instance when a person underplays symptoms through fear of loss of job. For identification of a non-cooperative or test-faking person, several safeguards and veracity-assessment methods have been developed, e.g. the use of null stimuli [25] and threshold variance [112]. Of course, all these questions must be taken into serious consideration as, to a large extent, they are related to test methodology and test procedure for QST.

The objectives of this paper are to summarise the fundamental neurophysiological base for QST and to discuss methodological and practical aspects associated with QST which are necessary to consider with respect to applicability and reliability as a screening or diagnostic aid for vibration-induced sensory neuropathy. QST for assessing sensory modalities related to vision and hearing is not addressed in this paper. Further, corresponding issues related to testing with electrophysiological and bedside methods are not addressed. Moreover, it is not an objective of this paper to discuss or to compare specific test results from QST conducted with different tools or testing equipment currently in use by clinicians or researchers.

**Neurophysiological basis for quantitative sensory testing**

In addition to providing mechanical protection for the deeper tissues of the hand, the skin has a number of functions. One is to house the huge number of sense organs that provide the central nervous system with information about tactile, thermal, deformatory and noxious events on the skin surface. Such information is not only necessary when using the hand in explorative tasks, but also essential for precise motor control of the hand [107]. Impaired sensory function and motor control of the hand is not only a serious handicap in most activities, but may also imply an increased risk for accidents.

When a vibrating hand-held tool is used, all mechanical energy which enters the operator’s hand-arm system has to be transmitted through the skin in contact with the handle. This vibration energy will cause compressive and tensile strain on the skin and underlying tissues.

In vibration-induced neuropathy, the conceivable target structures could be the end organs (e.g. mechanoreceptors, “cold” points, “warm” points, proprioceptors, nociceptors), the large myelinated (Aβ, Aδ), the thinly myelinated (Aδ) and the small-calibre non-myelinated (C) fibres. Large-diameter fibres mediate impulses from tactile perception (i.e. touch, pressure, vibration). Small-calibre fibres mediate thermal and pain stimuli.

**The tactile sense**

There are about 17,000–20,000 mechanoreceptive afferent units, or four different types, innervating the glabrous skin area of the human hand [60, 79, 98]. They are classified into four major categories on the basis of their adaptation and receptive field properties. Two types are fast adapting (FAI and FAII) and respond only when the skin is in motion. About half (44%) of the unit population are slowly adapting. The other two types are slowly adapting (SAI and SAIi) and they exhibit a response related to the amplitude of a constant deformation of the skin. At very low frequencies they also exhibit a response to skin motion. Type I units are characterised by small and well-defined receptive fields with a range between 3–500 mm² corresponding to circular areas of 2–8 mm diameter [62]. A fundamental task for the hand’s tactile sense is to provide the central nervous system with spatial details regarding skin deformation during manual manipulation and exploration. Type I units with small receptive fields are well suited for this task. Type II units have larger receptive fields, typically covering a whole finger or the great part of the palm. They have a single zone of maximal sensitivity