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Special Contribution

Current Perception Threshold for Assessment of the Neurological Components of Hand-Arm Vibration Syndrome: A Review

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Current perception threshold (CPT) has been proposed as a quantitative method for assessment of peripheral sensory nerve function. The aim of this review of selected reports is to provide an overview of CPT measurement for the assessment of the neurological component of hand-arm vibration syndrome (HAVS). The CPT values at 2000 Hz significantly increased for patients with HAVS. This result supports the previous histological findings that demyelination is found predominantly in the peripheral nerves in the hands of men exposed to hand-arm vibration. Diagnostic sensitivity and specificity were high for severe cases of Stockholm sensorineural (SSN) stage 3 compared with non-exposed controls, but not high for mild cases of SSN stage 1 or 2 and for carpal tunnel syndrome associated with HAVS. However, there are only a few studies on the diagnostic validity of the CPT test for the neurological components of HAVS. Further research is needed and should include diagnostic validity and standardizing of measurement conditions such as skin temperature.

Key words: current perception threshold; hand-arm vibration syndrome; neurological symptoms

Hand-arm vibration syndrome (HAVS) consists of vascular, neurological and musculoskeletal components. The neurological symptoms of HAVS include tingling and numbness at times other than during and immediately after vibratory tool use, the signs of loss of sensation, poor finger co-ordination, and an inability to do fine work (McGeoch et al., 1994). The diagnosis of the neurological component of HAVS is usually made clinically. Quantitative sensory tests such as vibration threshold and temperature threshold have been used for the assessment of HAVS (Ekenvall et al., 1986; Swerup and Nilsson, 1987), but no single test has had sufficient sensitivity and specificity.

Abbreviations: HAVS, hand-arm vibration syndrome; CPT, current perception threshold; CTS, carpal tunnel syndrome; SSN, Stockholm sensorineural; VWF, vibration-induced white finger

Current perception threshold (CPT) has been proposed as a quantitative method for assessment of peripheral sensory nerve function (Katims et al., 1986). Using the standardized method of CPT, large myelinated A-beta fibers, small myelinated A-delta fibers and unmyelinated C fibers are evaluated selectively at 2000, 250 and 5 Hz frequencies, respectively. The CPT test has been described in patients with alcoholism (Katims et al., 1987), diabetes (Rendell et al., 1989), idiopathic carpal tunnel syndrome (CTS) (Nishimura et al., 2003) and uremia (Katims et al., 1991b). This test has also been used to identify vibration-induced neurological damage, although this is less commonly used. The aim of this review of selected reports is to provide an overview of CPT measurement for the assessment of the neurological components of HAVS.

Table 1. Reported CPT in the HAVS

Year of publication	Subject	Device and procedure	Measured finger	Result
1998	79 non-exposed controls, 171 exposed men	Telmest	Index finger, little finger	CPT test helped to identify the largest number of persons with diminished sensitivity
2001	20 non-exposed controls, 59 exposed men*	NM, AP	Right index finger, little finger [≥ 30°C]	Groups of SSN stages 1 to 3 had significantly increased CPTs of index and little fingers at 2000 Hz, compared with the control group. Diagnostic sensitivities of the groups of SSN stages 2 and 3 were 76.9% and 92.3%, respectively; the 95th percentile (specificity = 95%) of the CPTs of index and little fingers at 2000 Hz of the control group was considered within the normal limit
2007	162 subjects†	NM, AP	Bilateral index fingers, little fingers	In comparison to the SSN stages, the overall CPT test results showed reasonable sensitivity (right hand 80%, left hand 89%) to detect SSN stage 2 + 3. The specificity (right hand 28%, left hand 44%) was low
2009	157 subjects‡	NM, AP	Bilateral index fingers, little fingers	CPT was increased in SSN stages 1 and 2 + 3 in comparison to stage 0, but CPT did not discriminate well between stage 1 and stage 2 + 3. Polychotomous logistic regression indicated that the CPT measurements at 2000 Hz, corresponding to damage to large myelinated nerve fibres, were most predictive both of stages 1 and 2 + 3 in comparison to stage 0

Authors of the above-mentioned references:
1998, Zamysłowska-Szmytke.
2001, Kurozawa and Nasu: *Right hand SSN stage 0: 8, stage 1: 24, stage 2 + 3: 30.
2007, Lander et al.: †Right hand SSN stage 0: 8, stage 1: 24, stage 2 + 3: 30.
Left hand SSN stage 0: 8, stage 1: 128, stage 2 + 3: 26.
2009, House et al.: ‡Right hand SSN stage 0: 55, stage 1: 81, stage 2 + 3: 23.
Left hand SSN stage 0: 52, stage 1: 83, stage 2 + 3: 20.
[ ], skin temperature.
AP, automatic procedure; CPT, current perception threshold; HAVS, hand-arm vibration syndrome; NM, neurometer; SSN, Stockholm sensorineural.

Methods

A systematic literature search for CPT studies was conducted in the PubMed database in November 2009. The search terms were "hand-arm vibration syndrome" or "vibration-induced white finger (VWF)" and "current perception threshold". The PubMed search revealed 5 articles on HAVS or VWF and CPT. After reading the abstracts and methods we selected 4 articles. The other article was an animal experience study.

CTS frequently occurs in association with HAVS (Palmer et al., 2007) and the clinical discrimination of CTS from the diffuse sensorineural impairment in HAVS is difficult. We also conducted a systematic literature search with the search terms "carpal tunnel syndrome" and "current perception threshold" in the PubMed database in November 2009. The search revealed 16 articles. After reading the abstracts and methods, we selected 2 articles in which study subjects included industrial workers.

Results and Discussion

Table 1 lists the 4 articles on HAVS or VWF and CPT. The study described by Zamysłowska-Szmytke covered 250 men, including 171 work-

Table 2. Reported CPT in the CTS among industrial workers

Year of publication	Subject	Device and procedure	Measured finger	Result
1991a	16 assembly line workers*	NM, AP	Index finger	CPT evaluations detected abnormalities in 12 (75%) of the workers. Clinical findings were consisted with CTS in 8 of the 16 workers. Five of the 8 workers with clinical findings had abnormalities of CPTs. Seven workers had CPT abnormalities without clinical findings
1994	83 plant workers†	NM, AP	Index finger, little finger	CPTs were statistically unrelated to self-reported symptoms and to electrophysiologic findings that were suggestive of CTS. The test performance characteristics of CPT testing were low (sensitivity 66.7%, specificity = 59.7%)

Authors of the above-mentioned references:
1991a, Katims et al.: *16 assembly line workers with pain in their hand.
1994, Franzblau et al.: †83 plant workers consisted of 6 with CTS and 77 without CTS.
AP, automatic procedure; CPT, current perception threshold; CTS, carpal tunnel syndrome; NM, neurometer.

ers occupationally exposed to hand-arm vibration and 79 persons non-exposed to vibration (Zamysłowska-Szmytke, 1998). A multiple device Telmest was used to measure CPT. The CPTs were significantly higher in persons exposed to vibration than in controls. However, diagnostic sensitivity and specificity were not described.

Kurozawa and Nasu found that the mean CPT values for index and little fingers at 2000 Hz were significantly increased in 59 men with HAVS in comparison to 20 non-exposed controls (Kurozawa and Nasu, 2001). The patients with HAVS were classified according to the Stockholm sensorineural (SSN) stages (Brammer et al., 1987). The CPT measurements were carried out using the Neurometer (Neurotron, Baltimore, MD). The measurements were carried out on the volar surface of the tips of the index finger for the median nerve and the little finger for the ulnar nerve. In their study, diagnostic sensitivities of the groups of SSN stage 2 and 3 were 76.9% and 92.3%, respectively.

Lander et al. conducted the CPT test for 162 subjects referred for HAVS (Lander et al., 2007). The standardized method using the Neurometer was employed for all subjects. Their study indicated reasonable sensitivity (right hand 80%, left hand 89%) but a low specificity. The study subjects did not include non-exposed controls, and exposed controls included subjects with SSN stage 1, which corresponds to intermittent numbness, with or without tingling. This may have contributed to the low specificity. They concluded that current perception measurement are insufficient for diagnostic purpose but may have a role in screening workers exposed to vibration.

House et al. carried out CPT test to determine if CPT measurements in workers exposed to hand-arm vibration, and predicted the SSN stages after accounting for any proximal neurological lesions measured by nerve conduction tests and if so which specific frequencies were most predictive (House et al., 2009). All the participants were men who had been exposed to hand-arm vibration at work and who were assessed for HAVS. They reported that CPT was increased in SSN stages 1 and 2 + 3 in comparison to SSN stage 0, but did not allow good discrimination between the higher SSN stages. They also reported that neuropathy measured by nerve conduction was unrelated to the SSN stages. Polychotomous logistic regression indicated that the CPT measurements at 2000 Hz, corresponding to damage to large myelinated nerve fibers, were most predictive both of SSN stages 1 and 2 + 3 in comparison to stage 0.

Table 2 lists 2 articles concerning CTS and CPT among industrial workers. Katims et al. evaluated the utility of CPT measurements for the evaluation of nerve integrity in 16 factory workers

who were self-referred to the factory's occupational medicine clinic because of pain in their hand (Katims et al., 1987). CPT evaluations detected abnormalities in 12 (75%) of the workers. Clinical findings were consisted with CTS in 8 of the 16 workers. Five of the 8 workers with clinical findings had abnormalities of CPT testing. Seven workers had CPT abnormalities without clinical findings.

Franzblau et al. described the result of a survey of active workers who participated in a medical screening for CTS (Franzblau et al., 1994). The CPT results were statistically unrelated to self-reported symptoms and to electrophysiologic findings that were suggestive of CTS. The sensitivity and specificity were 66.7% (4 of 6 with CTS) and 59.7% (46 of 77 without CTS), respectively. They concluded that the CPT test can not be recommended for use as a screening procedure for detecting possible CTS among active industrial workers.

CPT device and procedure

CPTs were obtained with a Neurometer CPT in all selected studies except for one study (Zamysłowska-Szmytke, 1997). The Neurometer diagnostic examination employed a standardized procedure to generate quantitative measures of the functional integrity of sensory nerves. The standardized automatic protocol allows for the detection of attempts of possible deception by the test subject by confirming the validity of response, and prevents examiner bias.

The current output of the Neurometer is maintained at a constant level by a feedback circuit during testing, which standardizes the stimulus across various skin thickness and as alterations occur in electrode paste or skin resistance (Katims et al., 1986). Increased thickness of finger skin is often found in operators who use vibratory tools. This thickness may contribute to the differences in vibration or temperature thresholds. The CPT test can therefore compensate for the effect of skin thickness on sensory evaluation in workers using vibratory tools.

Skin temperature

In the study by Kurozawa and Nasu (2001), the fingers were warmed until the resulting skin temperature exceeded 30°C, if skin temperature was lower than 30°C. There is no mention of skin temperature measurements during the CPT test in other studies.

Skin temperature has an influence on quantitative sensory test such as the vibration threshold test (Karadecka, 1974). Finger skin temperature in a range from 27°C to 30°C is recommended for measurements of vibration perception thresholds (International Organization for Standardization, 2001). However, there has been no study of the effect of skin temperature on the CPT test.

CPT frequency and HAVS

The CPT test measures CPT at frequencies of 2000, 250 and 5 Hz corresponding to the activation of large myelinated A-beta fibers, small myelinated A-delta fibers and unmyelinated C fibers, respectively. The CPT values at 2000 Hz were significantly increased for patients with HAVS (Kurozawa and Nasu, 2001; House et al., 2009). Acute high exposure of the rat tail to vibration was associated with an increase in CPT at 2000 Hz but not at 250 or 5 Hz (Krajnak et al., 2007). These results support the previous histological findings that demyelination is found predominantly in the peripheral nerves of the hands of men exposed to hand-arm vibration (Takeuchi et al., 1988).

Diagnostic validity of neurological components of HAVS

Diagnostic assessment was carried out in 2 studies (Kurozawa and Nasu, 2001; Lander et al., 2007). The sensitivity and specificity ranged from 92% to 76.9%, and 95% to 28%, respectively. High sensitivity and specificity were found in severe cases of SSN stage 3 compared non-exposed controls (Kurozawa and Nasu, 2001). The diagnostic valid-

ity in mild cases of SSN stage 1 or 2 was not high. Classifications were made according to the SSN stage, which is mainly based on symptom. The SSN stage is not exactly a gold standard. The study described by Lander et al. showed a low specificity (Lander et al., 2007). The study subjects did not include non-exposed controls. The insufficient validity demonstrated in this study may be associated with the lack of the non-exposed controls and with using the SSN stage as the gold standard. Taking these factors into account, the validity may have been more acceptable.

CPT and CTS among industrial workers

There is increasing evidence that CTS may also be associated with hand-arm vibration exposure. A recent review (van Rijn et al., 2009) reported that the occurrence of CTS was associated with exposure to a high level of vibration, prolonged work with a flexed or extended wrist, high requirements for hand force, high repetitiveness, and their combination. This suggests that 2 types of neurological regions are present: those in the legion of the digital nerve fibers and/or sensory receptors and more proximal lesions, in particular at the wrist involving the median nerve (House et al., 2009).

There were only 2 published studies suggesting the utility of the CPT measurements for the evaluation of CTS among industrial workers. In one study (Katims et al., 1991a), the results do not provide a basis for determining the characteristics of a positive CPT test for screening industrial workers for CTS. The other study (Franzblau et al., 1994) described the result of a survey of active workers who participated in a medical screening for CTS. The CPT results were statistically unrelated to self-reported symptoms and electrophysiologic findings that were suggestive of CTS. The sensitivity and specificity were unacceptably low. In the study, however, there were only 6 CTS cases. Sample size was too small to determine the utility of the CPT measurements for the evaluation of CTS among industrial workers.

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