An instruction manual for two Quantitative Sensory Tests: Cold Stress Test and The Ten Test

Zakir Uddin
Joy MacDermid

Correspondence: Zakir Uddin, MScPT, PhD (candidate), School of Rehabilitation Science, McMaster University, IAHS-308, 1400 Main Street West, Hamilton, Ontario L8S 1C7, Canada; E-mails: uddinz2@mcmaster.ca, zakiru@gmail.com

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INTRODUCTION AND OVERVIEW

What is Quantitative Sensory Testing?

Quantitative Sensory Testing (QST) involves the application of a sensory stimulus, and evaluating the person's interpretation of that stimulus. QST encompasses a group of sensory examination methods that evaluate the minimum threshold, perception or integration of sensory inputs. For example, pain hypersensitivity can be detected by threshold tests that assess the least amount of sensory input required for detection, or to be experienced as pain. Thus, QST is a psychophysical testing approach that can evaluate the functionality from sensory receptors to the brain and thereby detect alteration and reorganization in the nociceptive pathways. By selecting different sensory inputs, it is possible to evaluate the sensory processing of both large and small fibers [1, 2]. QST is semi-subjective (combination of subjective and objective) in nature, which measures the intensity of stimulus for specific sensory perception rather than examiner's bias from physical examinations.

Why is QST better for sensory measurements of pain?

QST holds some potential beneficial qualities, compared to traditional neurological diagnostic tools. For example, more than 75% of the peripheral nervous system (PNS) consists of small fibers, but traditional diagnostic methods for PNS (e.g. Electromyography, Nerve Conduction Velocity, Evoked Potential) primarily focus on the large fibers. Nociception (pain sensation) transmits through small caliber A-delta and C fibers. QST can target these fibers by using frequencies that target small fibers or sensory stimuli that are preferential to these fibers (pain or temperature). QST is capable of detecting small fibre's negative and positive values (i.e. increased pain response and lowered pain threshold). A direct record of nociception (pain sensation) from the muscle is difficult; that is why QST is so important to assess musculoskeletal pain. Furthermore, it is impossible to measure the sensory inflow of pain, due to the initial sensory amplification of pain (peripheral sensitization). Another problem is peripheral input also acts as a trigger of central sensory amplification of pain. To assess the both components of pain amplifications, ideally need a combination of objective measures integrating peripheral and central activity. QST is a good choice for objective measurement capable of detecting both small and large fiber's negative and positive (hypo and hyper) values (Figure-1).

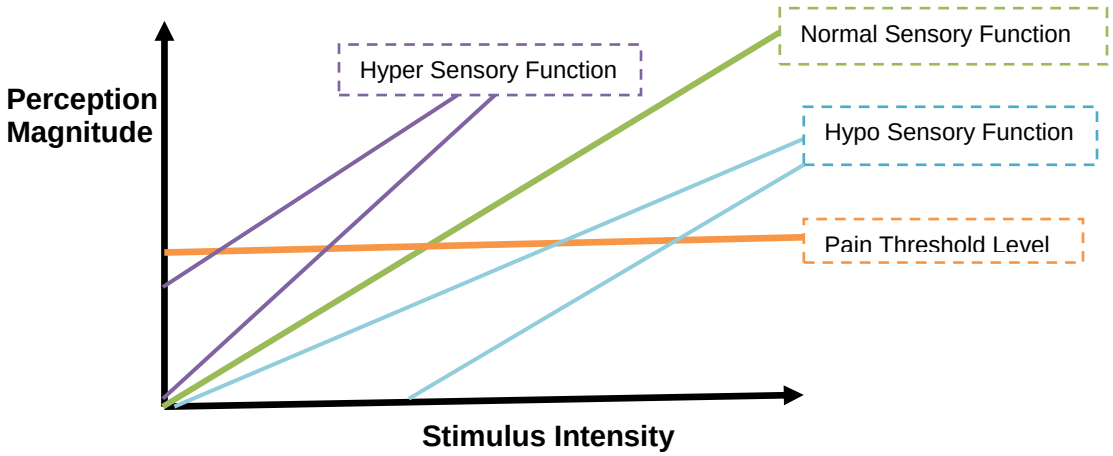

Figure 1: Stimulus-response ranges for normal, hypo, and hyper sensory function. A normal or altered slope can represent deviation from normal sensation. In some cases (e.g. neuropathic pain) a combination of hypo and hyper sensory function can be seen [1].

Why is QST beneficial for clinicians?

Recent studies suggest that QST may be useful in differential diagnosis, including detection of hypersensitivity and other pathogenesis of pain [1,3-5]. Assuming QST can detect subtypes of pain, these may be best managed by different treatment approaches; thus, testing may assist clinicians to direct patients to optimal treatments. Further, since the tests are quantitative they provide a potential means to monitor change over time in response to treatment (outcome evaluation) [4].

Rationale for the choice of the Cold Stress Test and The Ten Test

QST is a widely used pain assessment technique in laboratories but is less often used in clinical practice Clinicians are not as familiar with the techniques, and most of the QST tests are generally thought to be expensive. The proposed two QST techniques (see Table 1 for a comparative overview of the two test) might be potential clinical pain assessment tools for better identification of prognostic factors, monitoring, and optimizing treatment plans. Because they use inexpensive equipment, they are feasible even in a small clinic with limited equipment resources. Furthermore, a combination of these two simple tests provides a more comprehensive assessment of pain fibers (large diameter slow adapting A-β fiber and small diameter fast adapting A-δ and C fibers). The reliability and validity of the proposed two tests has been already been well examined and supports clinical use [6,7,8,9,10,11-14].

Table 1: A comparative overview of the Cold Stress Test and the Ten Test

Test Name	*Application Method*	*Advantages*	*Disadvantages*	*Cost Analysis*	*Nerve*
Cold Stress Testing (CST) [14].	ICE = Immersion in Cold-water (at 12°C) and Evaluation (5 min of cold exposure with 10 min recovery monitoring).	A practical simple standardized protocol that is clinically applicable, inexpensive, and reliable [14]).	Temperature of ice water maintain may consume more time that may not be feasible in busy setting.	$30 to 40 (need thermometers, stop watch, and an insulated container with ice water)	Small (A-δ and C) fiber [15]
The Ten Test [12]	Test is based on comparing a light moving touch stimuli (provided by examiner) to a test area and comparing that to an area of "normal" sensation. The rating is verbally rated from 10-1 with anchors 2 moving touch.	Rapid and simple sensibility test without any equipment requirements. Ratio between normal light moving touch and diminished moving touch compared with a known scale of sensibility (reliable and valid).	Only comparable to contralateral innervated body part within same dermatome.	Evaluation requires no instrumentation (virtually no cost).	Mainly adaptive large (A-β) fiber in glabrous skin [13, 16,17]

TEST DESCRIPTIONS: THE COLD STRESS TEST

Background of the Cold Stress Test (CST)

Cold stress (also referred to as cold intolerance) is a kind of hypersensitivity and is common after peripheral nerve injury or surgery. The incidence has been found more than 80% after nerve injury or surgery of the upper extremity [18,19]. Cold intolerance (sensitivity) is characterized by discomfort, pain, stiffness, altered sensibility or color change associated with cold exposure [8,20]. Cold sensitivity defined as the "trauma induced cold associated symptoms" [20]. Neural and vascular factors are explored for explain the aetiology of cold intolerance, but neural causes are favoured [18]. Cold responses are altered in many clinical conditions, such as whiplash associated disorders [21-24,29], complex regional pain syndrome [25], and hand vibration syndrome[7,9,26]. Cold intolerance is a good indicator to detect pain hypersensitivity [21,29], an important prognostic factor [22-24,27,29] and affects both the functional capability of the hand and overall quality of life [8].

CST protocol development

Cold provocation testing is a measure of cold intolerance. A literature review was conducted to justify a feasible standardized objective clinical test protocol for cold intolerance test [7,9,14,26,27]. Furthermore, the International Organization for Standardization (ISO) recommended water temperature of 12 °C (at room temperature of 20-22°C) and an immersion period of 5 minutes as a standard method parameter for the cold stress test [28]. In view of the recovery period, 10-minute follow-up was found to sufficient for significant improvement of temperature after immersion [14,27]. Digital skin temperature measurement is a standard component of the cold stress test. The test-retest reliability of a CST protocol (using digital skin temperature measurement) was found to be excellent (average ICC = 0.81 to 0.86) [14]. Subjective reporting during cold intolerance was also found to be reliable [14, 27], so a simple but reliably used self-reported pain measure (numeric rating scale) was added to the protocol.

Established Parameters, measurement, and instruments of CST

- ✓ Cold water temperature = 12 °C,
- ✓ Immersion time = 5 minutes,
- ✓ Monitoring/recovery time = 10 minutes,
- ✓ Room temperature = 20 to 22 °C,
- ✓ Pain measure in Numeric Rating Scale (NRS) = Just before and after immersion, and at the end of the test.
- ✓ Digital temperature measure (in °C) = Before and after immersion, at the middle and end of the recovery period.
- ✓ Instruments = A medical infrared skin thermometer, a pool thermometer, a stop watch, an insulated water container, and water with ice cubes (Figure 2 and 4).

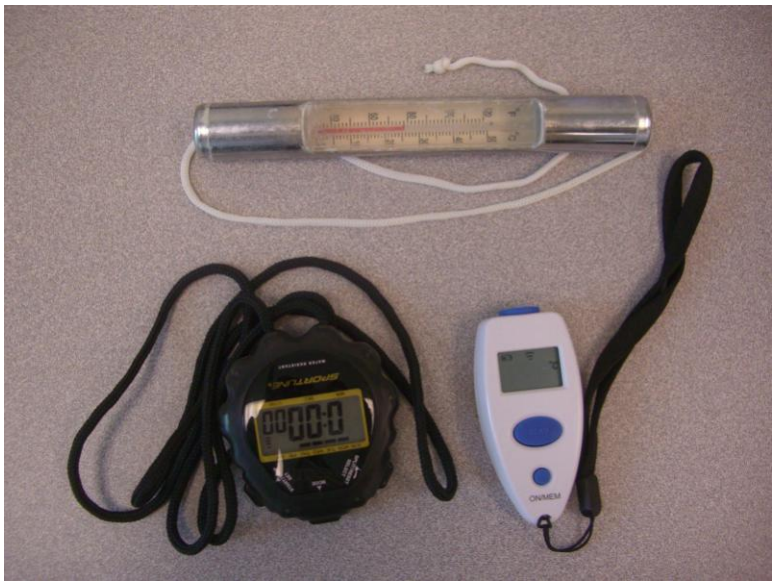

Figure 2: Instruments of CST: Top- Pool thermometer is for cold water temperature measure inside the insulated container ; Bottom Right-Temperature recording Infrared Skin thermometer is used to measure temperature of the target digit ; Bottom Left- Stop watch for time monitoring

CST considerations and contraindications

General considerations: Current medical status and medications/therapy, past vascular/cardiovascular surgery, presence of any risk factors for arterial disease, unable to tolerate 5-minutes immersion.

Indications: Pain or paresthesia, arterial insufficiency, color changes of the digits in cold exposure.

Contraindications: Open areas or ulceration of the digits, abnormal digital pressure, digital artery disease.

Assessment process (steps of CST procedure)

1. Acclimatization: Patient rests for 15 minutes (adaptation period) to acclimatize to the testing room environment (temperature of 20-22°C). The patient is instructed to rest affected hand with palm facing up on a table at the level of own heart.

2. Baseline measures: At the end of this resting time the patient is asked to rate current pain status on an 11 point numeric rating scale (0 = no pain, 10 = the worst imaginable pain). A medical infrared skin thermometer is used to record temperature from target digit at 1-minute intervals for 2 minutes to record baseline and pre-immersion skin temperature. Patient is asked to maintain a stable position and refrain from moving hands while resting and during immersion.

3. Immersion : Patient immerses his hand, up to the ulnar styloid process, in an insulated container of cold water at 12 °C. The temperature is continuously monitored throughout the test using a pool thermometer to verify the temperature reading. Water temperature is maintained within one degree of

target value. The tester should stir the water in the container roughly every 20 seconds to evenly disperse the water warmed by the patient's hand. Patient is cautioned to avoid touching the sides or bottom of the container.

4. Retesting: Following 5 minutes of immersion the patient removes the hand and places it palm up on a dry towel on the table. The tester has to quickly dry the patient's hand and subsequently record the temperature of target digit at 1-minute intervals for the next 10 minutes.

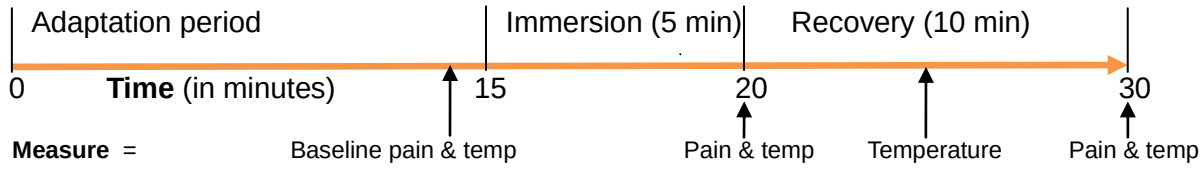

Figure 3: Summarized test protocol and timeline

Figure 4: Cold provocation in an insulated container of 12°C water. Patient immerses hand and is instructed to refrain from touching the sides or bottom of the container.

Interpretation of CST results

Changes in pain (NRS score) and temperature are observed and compared before and after immersion for sensory evaluation. At the end of recovery period, failure of the temperature and pain scores to return to baseline is considered as sensory disturbance (intolerance). Reduction of pain score (elevated cold threshold) is an indicator for neuropathy and elevation of pain score (reduced cold threshold) is an indicator for hypersensitivity. In addition, significant change of baseline and after immersion temperature measures are also an indicator of cold intolerance. The protocol can be repeated for unaffected or less affected hand for better comparison.

Benefits and Limitations of CST

Benefits for clinicians: The protocol measures limb digit recovery by a reliable and objective test augmented with patient self-reported ratings. Together with other valid and reliable subjective measures, this test can document and describe the sensory perception and functional disability associated with post-traumatic or post-surgical cold intolerance. While the exact pathophysiology of cold intolerance is unknown, the association with disability and loss of productive function is apparent to clinicians. However, it is also important to know if the patient is at risk of not responding to therapy.

Limitations: Test results may be impacted by several variables, including:

- season (less score in winter compared to summer),
- food intake (test should have to do between 1-4 hours after a meal),
- gender ,
- smoking within 4 hours,
- Alcohol within 12 hours.

TEST DESCRIPTIONS: THE TEN TEST

Background of The Ten Test

The 10-test (an instrumentless quantitative sensory test) was first described by Strauch and colleagues in 1997 [12]. In this test, the patient rates his or her perception of a light touch (given by examiner's hand) on a scale of 1-10 (where 10 is the value of the normal area). Patient compares the feeling of test area with normal area when the examiner lightly touches the normal area and simultaneously touches the abnormal area. Basically, patient compares the abnormal sensibility based on an automatic ratio (between normal light moving touch and diminished moving touch) and report to the examiner. The 10-test has been found to be reliable and repeatable. Inter-observer reliability was excellent (ICC = 0.91) [12] and very strong agreement (κ =1.00, $p<0.003$) was found between examiners [13]. Consistent with this, good to excellent intra-observer reliability (ICC = 0.62 to 0.90, $p<0.05$) [12] evaluated whether the stimulus pressure was delivered equally to the test and normal area. Moreover, multiple studies demonstrated the 10-test is a reliable and valid clinical test [10-13, 30] and may be used for outcome measurement [32-34]. Comparison of the 10-test with other sensory testing techniques (e.g. weinstein enhanced sensory test with calibrated monofilaments, static two-point discrimination, moving two-point discrimination, and pressure specified sensory device) [10] supported the superiority of the 10-test for:

- clinical use in patients age > 5 years [13]
- different conditions of upper [10,30,33] and lower extremities [34],
- pre and post operative sensory evaluation [12,31,32].

Simplicity, capacity to detect subtle sensory changes, and ease of test administration are the most significant practical appeal of the 10-test. It provides an option for clinicians in busy clinical settings , or where quantitative sensory testing equipment is unavailable.

Assessment process of the 10-test

1. Selecting a normal body part: If the plan is to test finger sensibility, then the normal body area to be compared may be the same digit on the opposite hand or the opposite side of the same digit or another digit on the same hand. If all digits are suspected to be affected, then another body area may be chosen, taking into consideration similar innervations density (e.g. lips are similar to palmer aspect of digits compared to glabrous skin areas and types of nerve fibers).

2. Initially, the selected normal area is lightly stroked by the examiner's finger, and the patient is explained that this feeling is their best sensation, which is equivalent to a score of 10 on a 1-10 scale (Figure 5).

3. The examiner lightly strokes the normal area and simultaneously strokes the abnormal area maintaining an equal pressure for both normal and abnormal part (Figure 6).

4. The patient is asked to compare the feeling of test area with normal area on a 1-10 scale where 10 is equal to the best sensibility.

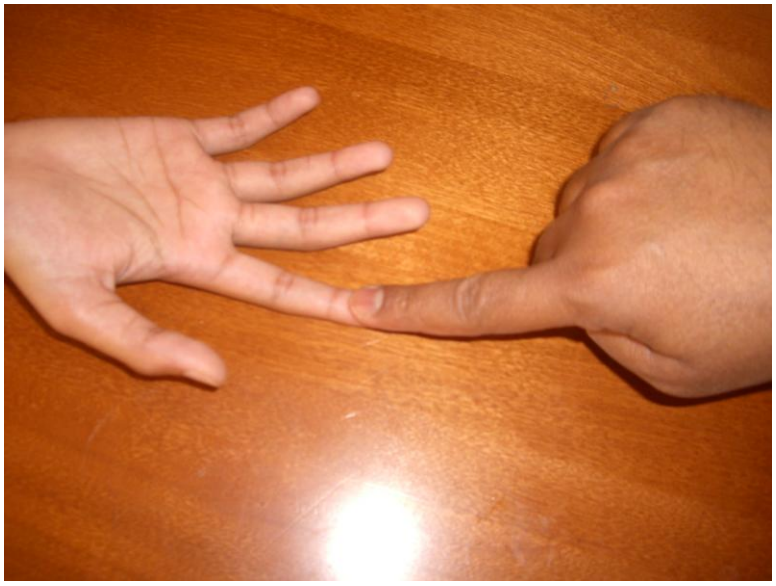

Figure 5: The examiner (left) stroking a normal part (right) to elicit patient's normal sensibility at palmer aspect of the tip of a digit, which is assigned a score of10 on a 1-10 scale.

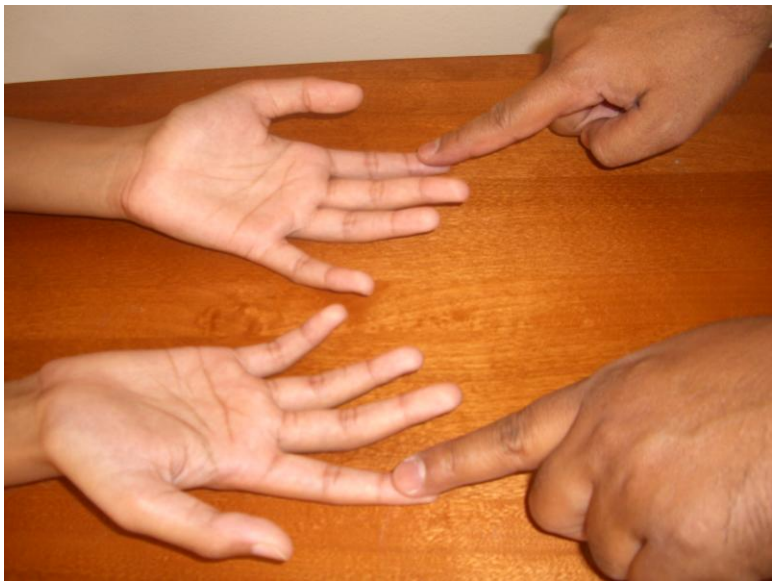

Figure 6: The normal and abnormal area being simultaneously stroked, with equal pressure maintained by examiner's both fingers (left). The procedure produces an analog ratio of the abnormal body area compared with the normal area.

Interpretation of 10-test results

The response from the patient concerning the abnormal area is recorded as a fraction out of 10 between 1/10 to 10/10 (diminished to normal sensory perception). The test may be repeated (according to the need and time) to produce an average score.

If any test area is found to be more sensitive than normal, then the interpretation would be different. In case of hyperesthesia (sensory hyperfunction that is common in abnormal pain response like hyperalgesia and allodynia) , the normal area sensation score is assigned 1 (instead of 10) in a 1-10 scale, then test area compared by a fraction between 1/10 to 10/10 (normal to increased sensory perception).

Benefits and limitation of the 10-test

Benefit for clinicians: The 10-test is semi-subjective in nature, and a more feasible approach than self reported sensory measures conducted without the reference of a stimulus. Since the normative value of different quantitative sensory tests are not well established, use of the comparative ratio score for an individual patient is a simple, inexpensive and convenient QST method.

Limitations: The test requires patient cooperation and might have some cognitive bias. Maintaining equal pressure and a precise test area for simultaneous stimulation of both the normal and abnormal part may be challenging.

Originally, the test was developed for hypoesthetic (sensory hypofunction) conditions. If the patient presents with hyperesthesia (sensory hyperfunction or abnormal pain response), or paradoxical allodynia over a hypoesthetic territory [35], then interpretation would be different.

Contraindications for this test include open wounds on or near the test areas or absence of an available normal reference territory.

OVERALL CONCLUSION

The two QST methods described here can provide a detailed sensory profile that will compliment other clinical assessment tools. A video on the test procedure of these two QST techniques is available at, http://www.youtube.com/watch?v=ktvjsqbIfUM. In comparison to the mostly instrument-based QST, these two tests present reliable, feasible and economical choices for clinicians. Both tests have good diagnostic and prognostic value. Despite the identified limitations of these types of semi-subjective measure, their simplicity and cost effectiveness increase the utility for clinical evaluation of sensory function in different disease conditions.

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