Thermal Sensitivity Tester

Device for Quantitative Assessment of Thermal Sense in Diabetic Neuropathy

JOSEPH C. AREZZO, HERBERT H. SCHAUMBURG, AND CHARLES LAUDADIO

SUMMARY

The Thermal Sensitivity Tester (TST) is a portable device designed to quantify the ability to discriminate small differences in temperature at the distal extremities of the hands and feet. The testing surfaces are two identical nickel-coated copper plates, which can be set and maintained over a wide range of temperature levels. The threshold for detecting the colder surface is determined using a two-alternative, forced-choice algorithm. The mean threshold in the normal population is 0.67°C and 1.01°C for the index finger and great toe, respectively. The TST is especially useful in diabetic neuropathy and for rapid screening of large populations under field conditions. DIABETES 1986; 35:590–92.

Small nerve fiber dysfunction is characteristic of diabetic peripheral neuropathy, in contrast to other metabolic toxic neuropathies, which are heralded by symptoms of large-fiber disease. Clinical assessment of small-fiber nerve function is often perfunctory, usually limited to casual examination with a pin and a cold object. Likewise, standard electrophysiologic techniques principally measure large-fiber function. This report describes a portable device, the Thermal Sensitivity Tester (TST, Sensortek, Inc., Clifton, New Jersey) designed to monitor the integrity of small nerve fibers by quantifying thermal thresholds in the distal portion of upper and lower limbs.

The TST consists of two identical 25-cm^2 nickel-coated copper plates connected to separate power units and perfused with water in series (Figure 1). Thermal electrical cooling or heating is achieved with the Peltier principle.[1] The temperature can be set to within 0.1°C, spanning a 50.0°C range and can be changed at a rate exceeding 1.0°C/s.

Throughout testing, skin temperature for the index finger and great toe should be maintained between 28 and 34°C. These temperatures can be directly measured on the digital display of the TST. During testing, the fingertips or toe pads contact the stimulating surface of each plate. One plate is maintained at 25.0°C while the temperature of the second plate is varied up or down using a series of fixed-step digital controls. The temperature of each plate and the difference in temperature between the plates is continuously displayed on separate digital meters, accurate to 0.1°C. Thresholds are determined using a two alternative forced-choice procedure that requires approximately 10 min per site tested. For each trial the subject is requested to report which of the two plates feels colder. The position of the colder plate is under experimental control, determined by a randomized sequence. The subject alternately contacts each plate for approximately 2 s with sufficient pressure to blanch the nail of the finger or toe. For the initial trial, the temperature difference between the plates is set at a level detectable 100% of the time. An initial temperature of 6.0°C has proved sufficient for most subjects in the 20- to 50-yr range. This level should be increased for subjects with neuropathy, for older individuals, or when testing the feet. If the subject is correct on the initial trial, the temperature difference is reduced by approximately 10% for the following trial. After the first error, the identical temperature difference (randomly allocated with respect to the colder plate) is repeated for a total of two or three trials. If the stimuli are correctly identified on two of the three trials, the temperature setting is lowered 10% and the process is repeated. If errors are made on two consecutive trials, the temperature setting is raised 10%. Testing is continued until it can be determined that the subject is correct on only 50% of the trials. Under field conditions, this value can be approximated by completing testing after the subject has made a total of five errors and by averaging the temperatures for the five errors combined with the five lowest correct scores.

From the Department of Neuroscience (J.C.A.), Neurology (J.C.A., H.H.S.), and Pathology (H.H.S.), Albert Einstein College of Medicine, Bronx, New York; and the Department of Medicine, Brown University (C.L.), Providence, Rhode Island.

Address reprint requests to Joseph C. Arezzo, Ph.D., Rose F. Kennedy Center, Rm. 322, Albert Einstein College of Medicine, 1300 Morris Park Avenue, Bronx, New York 10461.

Received for publication 8 April 1985 and in revised form 3 December 1985.

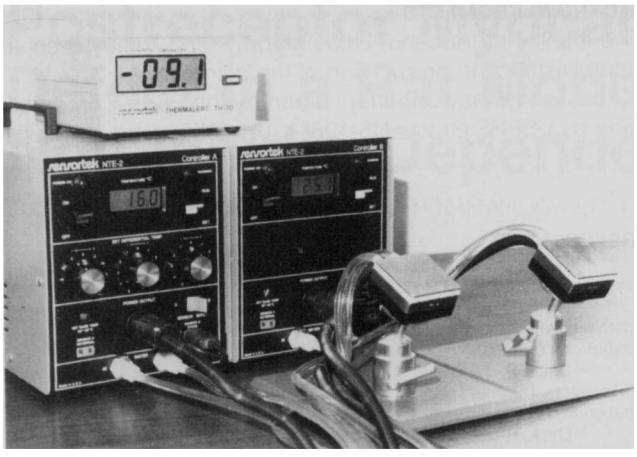

FIGURE 1. The Thermal Sensitivity Tester, including two digitally controlled power units, two standard plates, and a differential thermometer. The water pumping unit is not shown.

RESULTS

The mean thermal threshold for the index finger, determined in 100 normal subjects between the ages of 18 and 65 yr, is 0.67°C, with a standard deviation of 0.31°C. The mean thermal threshold for the great toe in a similar population is 1.01°C, with standard deviation of 0.61°C. With age, there is an apparent increase in both threshold and variance (Figure 2); however, these trends were not statistically significant within the sample size of the present study. The correlation coefficient for thermal thresholds in the hands and feet for individual subjects in the normal group is 0.71.

Ten subjects were repeat-tested on 10 occasions separated by at least 1 day. The coefficient of variation within this group ranged from a low of 8.3% for the index finger of a 22-yr-old laboratory technician to 47.1% for the great toe of a 66-yr-old retired construction worker. The mean coefficient of variation across the group was 19.0% and 26.6% for the index finger and toe, respectively. The following two case histories demonstrate the use of the TST in individuals with nervous system disease.

Case 1: pyridoxine neurotoxicity. A 41-yr-old housewife consumed 6 g of pyridoxine daily for 6 mo before noticing unsteady gait and numbness of the fingertips and toes. This was followed by progressive numbness and loss of sensation up to the midthigh, of the entire hands, and the face. On examination there was distal stocking-glove sensory loss and a broad-based gait; strength was normal, and tendon reflexes were absent throughout. Quantitative upper limb testing with the TST revealed a threshold >10 SD above normal. After discontinuation of pyridoxine, her thermal threshold improved substantially after 3 mo, although she had not yet perceived any lessening of her symptoms. Her symptoms dramatically improved, and the thermal threshold fell to normal limits within 6 mo.

Case 2: diabetic neuropathy. A 35-yr-old carpenter with long-standing, insulin-dependent diabetes noticed that he had numbness of the feet and developed painless bruises of the toes. By age 38 yr, he was impotent and had an infected ulcer at the base of the left great toe. On examination, abnormalities were confined to the lower limbs where there were absent tendon reflexes, diminished sensation to pain, touch and thermal senses in a "stocking distribution." Strength and position senses were normal throughout. Scores on initial toe pad TST testing were symmetrical and were 3 SD units above normal. Within 1 yr of initial testing, the threshold had risen to greater than 8 SD units above normal in the feet. Thermal threshold of the hands has remained within normal limits, but they are currently 2.3 SD units above age-matched controls.

DISCUSSION

The present study demonstrates that the TST is a reliable device for the rapid assessment of thermal sensation. Cardinal features include stable and accurate control over temperature and use of two alternative forced-choice psychophysical procedures. Thermal thresholds determined using the TST in the normal population are substantially lower than those reported with other portable thermal devices where temperature is continuously and predictably changing[2] or difficult to control accurately.[3] Both the means and standard

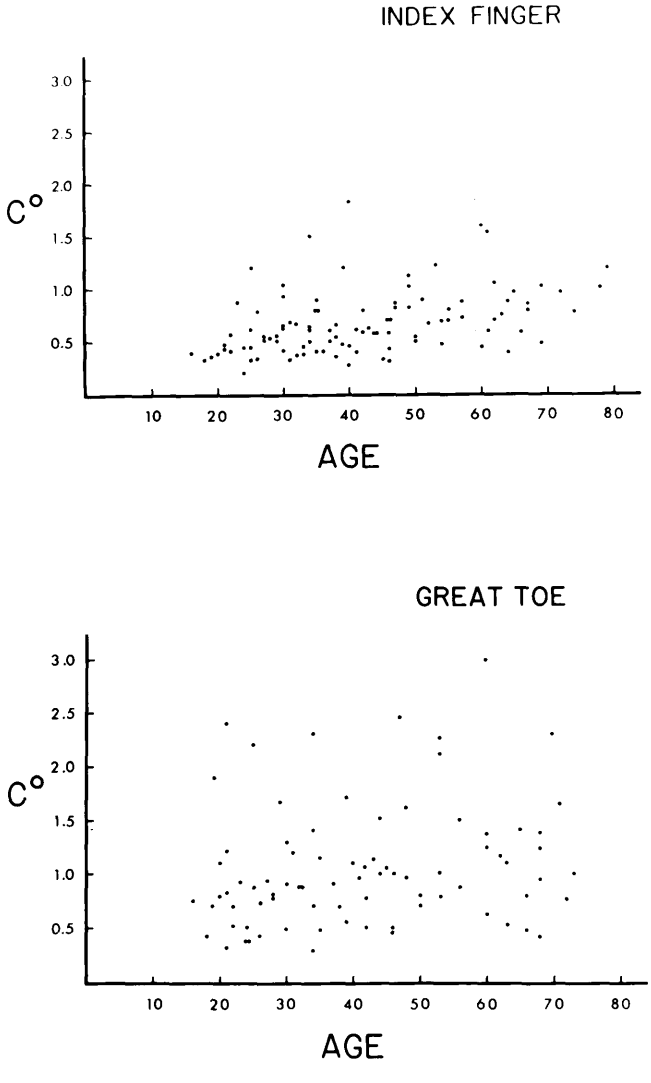

FIGURE 2. Thermal thresholds for the index finger and the great toe, plotted against age for 100 subjects free of any history of neurologic disease or diabetes.

deviations of thermal thresholds reported in the present study are similar to those recently described using elaborate computer-driven systems.[4,5]

Although accurate, the TST has several shortcomings. The testing algorithm selected for use under field conditions only approximates the ideal psychophysical procedure. The force and duration of contact with the stimulating surface is standardized; however, it can vary across trials and subjects. The variability introduced by these factors may limit the ability of the TST to detect subtle alterations in small-fiber function.

The TST has proved useful for repeated screening of peripheral nerve dysfunction in large populations and has been especially helpful in assessing the small-fiber component of diabetic neuropathy. In a recent study using the TST, diabetic subjects with clinically evident polyneuropathy had significantly elevated thermal thresholds as compared with normal subjects or diabetic subjects with no evidence of neuropathy.[6] Reliability and its quantitative features render the TST valuable in following the longitudinal course of individual diabetic patients or for statistical comparison of groups receiving different treatment regimens. The TST, used in concert with portable devices for quantitative assessment of large-fiber dysfunction,[7,8] also affords the opportunity to evaluate quickly overall sensory function in individuals with those conditions (syringomyelia, toxic and metabolic neuropathies) that have differential effects on the modalities of somatosensory function.

ACKNOWLEDGMENTS

We thank Tina Rubano, Linda Murphy, and Nancy Brennan for assistance in preparation of the manuscript.

This work was supported in part by the Pfizer Corporation and by USPHS Grants NS-19611, 0H-00535, and 0H-00851.

REFERENCES

[1] Kenshalo, D. R.: Improved methods for the psychophysical study of the temperature sense. Rev. Sci. Instrum. 1963; 34:883–86.

[2] Fruhstorfer, H., Lindblom, U., and Schmidt, W. G.: Method for quantitative estimation of thermal thresholds in patients. J. Neurol. Neurosurg. Psychiatry 1976; 39:1071–75.

[3] Dyck, P. J., Curtis, D. J., Bushek, W., and Offord, K.: Description of "Minnesota Thermal Disks" and normal values of cutaneous thermal discrimination in man. Neurology 1974; 24:325–30.

[4] Dyck, P. J., Zimmerman, I. R., O'Brien, P. C., Ness, A., Caskey, P. E., Karnes, J., and Bushek, W.: Introduction to automated systems to evaluate touch-pressure, vibration, and thermal cutaneous sensation in man. Ann. Neurol. 1978; 4:502–10.

[5] Dyck, P. J., Karnes, J., O'Brien, P. C., and Zimmerman, R.: Detection thresholds of cutaneous sensation in humans. *In* Peripheral Neuropathy, 2d edit. Vol. 1. Dyck, P. J., Thomas, P. K., Lambert, E. H., and Bunge, R., Eds. Philadelphia, W. B. Saunders, 1984:1103.

[6] The Sorbinil Neuropathy Study Group: Tactile (TT) and thermal threshold (ThT) testing in diabetic neuropathy (DN). Abstract. Diabetes 1985; 34:12A.

[7] Arezzo, J. C., and Schaumburg, H. H.: The use of the Optacon as a screening device: a new technique for detecting sensory loss in individuals exposed to neurotoxins. J. Occup. Med. 1980; 22:461–64.

[8] Arezzo, J. C., Schaumburg, H. H., and Petersen, A.: Rapid screening for peripheral neuropathy: a field study with the Optacon. Neurology 1983; 33:626–29.