

# Steel Ball-Bearing Test Assesses Protective Sensation

This test may be used to determine the level of protective sensation in the diabetic foot.

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**F**oot lesions are a frequent complication associated with diabetes. Their etiology is multifactorial; neuropathy plays a pivotal role in the pathogenesis of ulceration. Sensory loss, impaired foot structure and altered biomechanics, in combination with foot injury due to treading on a sharp object or wearing ill-fitting shoes, predispose tissue to breakdown.

In a recent issue of *Diabetologia*, we described the steel ball-bearing test, a new test for the evaluation of protective sensation in the diabetic foot. This test is based on the pathophysiology of neuropathic ulcer

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development due to unperceived extrinsic trauma. The study enrolled 39 patients with diabetic neuropathy and prior neuropathic ulcer; 36 patients with diabetic neuropathy without neuropathic ulcer; 34 patients without diabetic neuropathy and 21 healthy controls. Exclusion criteria included age <17 years or >75 years and peripheral arterial occlusive disease or other potential causes of neuropathy.

## ESTABLISHED TESTS

Neuropathy was diagnosed by means of neuropathy disability score (NDS). Patients were examined with established neuropathy tests, namely the 10-g Semmes-Weinstein monofilament, the vibration detection threshold (VDT) and the thermal detection threshold (TDT) for cold and hot.

Patients were also examined with a specially designed steel ball-bearing attached to a commercially available plaster. Examination with the steel ball-bearing was performed on the plantar area over the second metatarsal head of each foot. An empty control plaster was applied on the contralateral foot. Callus was appropriately removed prior to examination.

Five ball-bearings were used: ball-bearing 1 (1.5 mm in diameter), ball-bearing 2 (2.0 mm in diameter), ball-



Figure 1. The steel ball-bearing, as applied to a patient on the right foot. A control plaster was applied to the left foot.

**TABLE 1. TPT, VPT, MONOFILAMENT AND NDS TEST RESULTS**

TEST	SENSITIVITY	SPECIFICITY
<b>Neuropathy</b>		
Monofilament	67.9%	90.5%
TDT (cold)	89.3%	71.4%
TDT (hot)	88%	70.5%
VDT	69.3%	85.7%
<b>Neuropathic ulcer</b>		
NDS	84.7%	41.7%
Monofilament	77.9%	43.1%
TDT (cold)	87.2%	36.1%
TDT (hot)	79.5%	41.1%
VDT	79.5%	91.0%

bearing 3 (2.5 mm in diameter), ball-bearing 4 (3.0 mm in diameter) and ball-bearing 5 (3.5 mm in diameter). Patients were asked to walk barefoot on flat ground. The examination began with the smallest diameter ball-bearing and was increased until the patient could feel it while walking. The ball-bearing score (range 1 to 6) was defined as the smallest ball-bearing that the patient could feel. A score of 6 indicated that the patient could not feel any of the ball-bearings. Both feet were examined and the higher result for right and left was used as the ball-bearing score because it denoted more compromised protective sensation. Physicians conducting the steel ball-bearing test were blinded to the results of neurological examination.

### CORRELATED WITH THE NDS

A high ball-bearing score was significantly more frequent in patients with neuropathic ulceration than in neuropathic patients without ulceration or diabetic patients without neuropathy ( $P < 0.001$ ). Significantly frequent high ball-bearing scores extended to neuropathic patients without ulceration versus patients without neuropathy ( $P < 0.001$ ). Both intra- and interobserver reproducibility of the ball-bearing test were good. Ball-bearing scores significantly correlated with the NDS, monofilament, VDT and TDT scores ( $P = 0.001$ ).

The ball-bearing score had a sensitivity of 84% and a specificity of 100% for impaired protective sensation due to neuropathy, and a sensitivity of 84.6% and a specificity of 86.1% for detection of patients with prior

neuropathic ulceration. Compared with the other tests, the ball-bearing belonged to the most sensitive and specific among all diagnostic tests used (Table 1). A significant association between high ball-bearing score ( $\geq 4$ ) and history of previous neuropathic ulcer was demonstrated. Hence, the ball-bearing test appears promising in the identification of patients prone to ulceration.

Patients who could not feel the ball-bearing sometimes wanted to know more about diabetic neuropathy, and sometimes realized that their foot apparel did not properly fit. These patients were given instructions on obtaining suitable footwear. Accordingly, the ball-bearing test showed the danger of unperceived trauma to the patient, thus contributing to patient education. This is an additional advantage of the new test.

### CLINICAL APPLICATION

These results indicate that the steel ball-bearing test may be a useful clinical screening test for protective sensation. The strengths of the new test lie in the high sensitivity and specificity as well as in the contribution to patient education. The weakness of the ball-bearing test is that it is not yet widely available and is relatively time-consuming (15 to 20 minutes).

We concluded that the steel ball-bearing test appears to have a high sensitivity and a high specificity both for the evaluation of protective sensation and for detection of patients with prior neuropathic ulceration. This new test may prove valuable in detection of patients at high risk for foot ulceration. ■

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