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Chapter 6

The Paper Grip Test for Screening on Intrinsic Muscle Paralysis in the Foot of Leprosy Patients

From: The Paper Grip Test for Screening on Intrinsic Muscle Paralysis in the Foot of Leprosy Patients
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INTRODUCTION

Foot problems are one of the most common causes of 'dehabilitation' and morbidity in leprosy. Mostly, there is a combination of sensory, motor and autonomic nerve affection resulting in progressive loss of protective sensation, weakness and muscle atrophy.\textsuperscript{12} Approximately 10\% to 15\% of leprosy patients have impairments and disabilities involving their feet, especially plantar ulceration, drop-feet, claw feet and tarsal disorganisation.\textsuperscript{23} Recurrent ulceration in spite of protective footwear is the most frequent indication for admission in leprosy hospitals.

Although a lot of attention is paid to anaesthesia of the foot sole as a cause of foot problems in leprosy and other neuropathies of the foot, less attention is paid to paralysis of the intrinsic muscles. However, it is thought that anaesthetic feet without intrinsic muscle paralysis are not prone to ulceration.\textsuperscript{24} As paralysis of the intrinsic muscles of the hand leads to claw hands, paralysis of the plantar intrinsic musculature of the foot leads to claw toes.\textsuperscript{12} Intrinsic muscles contribute to the architecture of the longitudinal and transverse arches of the foot, which aid in the distribution of mechanical stresses especially during walking.\textsuperscript{3,19,20} Paralysis will lead to abnormal foot structure and increased peak-loads. Clawing of the toes due to intrinsic muscle paralysis also causes a shift in distal direction of the plantar fat pad below the metatarsophalangeal (MTP) joint, exposing the thinner part of the skin to pressure.\textsuperscript{7} Therefore, additional intrinsic muscle paralysis increases the risk of ulceration in anaesthetic feet by a factor of 10 to 12.\textsuperscript{23} The combination of anaesthesia and paralysis is found in 85\% of all ulcers; the majority is located in the forefoot, especially in the MTP joint region.\textsuperscript{8,23} Infectious conditions, like osteomyelitis, septic arthritis and septic tendosynovitis are most common complicating factors causing further deformation.\textsuperscript{14}

In the early stage of intrinsic muscle paralysis, education, self-care and special footwear can help prevent further deformities.\textsuperscript{4,15,21,22} Moreover, claw toe deformity and its consequences may be prevented and corrected by tendon transfer surgery, employing the long flexor of each digit. This procedure is only possible in flexible claw toe deformities and is preferable to procedures used for fixed claw toe deformities (arthrodesis with or without shortening of the toe) because it provides a partial restoration of function.\textsuperscript{13} Thus, just as with the early detection of sensibility loss, the early detection of intrinsic muscle paralysis has important implications for the prevention of impairment and deformity. In spite of this, there is no reliable manual test that can be used as a screening test for intrinsic muscle strength in leprosy patients, unlike the routine tests that are done for the examination of the extrinsic muscles or the sensibility of the foot.

The lack of a reliable screening test gave rise to the development of the Paper Grip Test (PGT) by W. J. Theuvenet and P.W. Roche, from The Anandaban Leprosy Hospital, The Leprosy Mission, Nepal in 1990. This PGT can be used as a screening test for plantar intrinsic foot muscle paralysis. The PGT resembles the Froment test for detection of intrinsic
hand muscle paralysis, where the patient has to hold a piece of paper between the pulp of the thumb and that of the index finger while the examiner tries to pull it away. This test becomes positive when the adductor pollicis, the first dorsal and the second palmar interossei muscles are paralysed, because the patient in an effort to hold on to the sheet, will flex the distal phalanx of the thumb before losing grip of the paper. In the PGT for the hallux, the patient will try to hold a piece of paper pressed between the pulp of the big toe and the floor, while the examiner tries to pull it away. If the flexor hallucis brevis is paralysed, the patient will flex the distal phalanx of the hallux before losing grip of the paper.

The purpose of this study was to investigate the reliability of the PGT as a screening test for intrinsic muscles weakness of the foot. We investigated the outcome of the PGT in leprosy patients compared to non-leprosy controls. Also, the correlations between the outcome of the PGT's and different factors such as foot sole sensibility, gender, age and type of leprosy were objectives of this study.

MATERIALS AND METHODS

The Paper Grip Test
Two variants of the PGT were conducted, PGT1 to detect intrinsic muscle weakness of the great toe and PGT2 to detect weakness of the combined intrinsic muscles of the lesser toes (second, third, fourth and fifth toe).

The Paper Grip Test of the great toe (PGT1). A paper slip is put under the great toe just distal to the MTP joint. While the examiner tries to pull the paper away, the patient offers maximal resistance. The hand of the examiner rests on the patient's knee assuring the heel is kept on the floor.

During the test the person (footwear and socks removed) sits up straight with hips, knees and ankles in 90° of flexion. The examiner supervises that patients stay in the same position and keep their heels on the floor during the test. Patients have to look at their feet, because leprosy patients with anaesthetic feet will not feel the paper, causing difficulty in holding the paper. The examiner puts a slip of strong rough paper under the phalanges of respectively the great toe (for the PGT1) or the four lesser toes (for the PGT2), just distal to the MTP joints (see photo-
The examiner tries to pull the paper away with gradually increasing power in a horizontal direction, while the person offers resistance. Solid rough paper (2x10 cm, 100g/m² type) that did not easily tear, and a smooth underground of concrete was used in all examinations.

The PGT was carried out up to three times when the patient was not able to grip the paper. The PGT was considered positive (abnormal), when it was possible to pull the strip away easily all three times. The test was considered negative (normal) when the patient was able to grip the paper at least one out of three times testing.

Patients and controls
In 1998, during a period of four months, leprosy patients (new patients and patients who came for follow-up) and non-leprosy subjects from the Purulia Leprosy Home and Hospital (The Leprosy Mission, Purulia, West Bengal, India) were examined for their intrinsic muscle function. Patients with paralysis of the long flexors and extensors of the toes, infective ulceration, rigid claw toes or other gross deformities were excluded. Patients with small non-infective ulcerations were not excluded. The non-leprosy subjects were volunteers without foot deformities, selected from the same background (family members of the patients and persons matched for social standing) in order to prevent bias due to different types of feet and footwear.

517 leprosy patients and 170 non-leprosy controls met the inclusion criteria. Information about age (<20, 20-39, 40-59 and >59) and type of leprosy (TT = tuberculoid leprosy, BT = borderline tuberculoid leprosy, BB = borderline leprosy, BL = borderline lepromatous leprosy, LL = lepromatous leprosy, PN = pure neuropathic leprosy) was obtained of each person. The proportion of males was 67.4% in the leprosy group and 66.5% in the control group. A majority of males corresponds with the general gender-distribution of leprosy. The mean age was 30.3 years in a range from 4 up to 81 years old. Of those 517 leprosy patients, 496 met the criteria for both feet and 21 patients for only one foot, so a total amount of 1013 leprosy feet were included in the study. The results of these 21 patients were only regarded in the analysis of the relation between outcome of the PGT and foot sole sensibility. The other analysis required both feet to be included (n=496).

Extrinsic muscle testing
Function of the tibialis anterior, the extensor digitorum longus, the extensor hallucis longus, the flexor digitorum longus, and the flexor hallucis longus were tested by means of isometric contraction against resistance in unloaded feet. For testing of the tibialis anterior, extensor digitorum longus and the extensor hallucis longus, the patient had to move feet and toes dorsally, while the examiner offered resistance to extension of the toe and fixed the ankle in 90° of flexion. For testing the flexor digitorum longus and flexor hallucis longus the patient moved his toes plantarwards, while the examiner offered resistance to the distal phalanges and fixed the proximal phalanges in a flexed position to relax the intrinsic muscles.
Sensibility testing
Sensibility of the foot sole was tested by means of a 10 gram Semmes-Weinstein monofilament. This has been described to be a reproducible method for detecting loss of protective sensation of the sole of the foot. After adequate explanation and demonstration, sensibility was tested at three regions: the first metatarsal head (medial plantar nerve), the fifth metatarsal head (lateral plantar nerve), and the heel pad (tibial nerve). The examiner gave a stimulus up to three times at each region. Sensibility was regarded normal when a patient was able to indicate all three regions of pressure stimulus with closed eyes at least one out of three times tested. A foot was regarded partially anaesthetic when the patient was able at least once to indicate the pressure stimulus at either one or two regions, and as totally anaesthetic when the patient was not able to indicate the pressure at any of the three regions.

Examiners
To diminish information bias, two examiners performed examination. The first examiner determined whether patients and controls met the inclusion criteria. This examiner also determined the function of the plantar intrinsic muscles of the foot by means of the PGT 1 and 2. The second examiner, a physiotechnician of the hospital staff, performed sensibility testing of the sole of the foot as part of a three monthly routine check up for leprosy patients. A third examiner was involved to measure the inter-observer variability of the PGT.

Validity and reliability of the Paper Grip Test
In seven leprosy patients with loss of protective sensation of the forefoot but normal PGT 1 and seven non-leprosy subjects with normal PGT 1 an experiment was done to test the validity of the PGT in determining plantar intrinsic muscle paralysis of the foot. In all 14 persons the tibial nerve of one foot was artificially blocked by injecting 5cc bupivacaine 1% inside the tarsal tunnel. After that the PGT 1 testing was repeated.
In three healthy persons we tested the activation of the plantar intrinsic muscles and long muscles of foot and toes, while performing the PGT1 by means of surface electromyography.
Inter- and intra-observer reliability was determined on the basis of the results of the examinations of 20 leprosy patients (n=40 feet) independently by the first and third examiner, alternately just after each other. Intra-observer variability was determined by examining 43 leprosy patients (n=86 feet) twice by the same examiner on two separate occasions with an interval of about three months.

Data analysis
The bivariate Pearson correlation-analysis was used to detect linear relations between outcomes of the PGT’s and leprosy, foot sole sensibility, gender, age and type of leprosy. Through this analysis it is possible to present the relation between two variables, correcting it for other variables by means of the partial correlation coefficient (pcc). A p-value <0.05 was regarded as significant.
Agreement in inter- and intra-observer examinations was analysed separately for PGT1 and 2 through the non-weighted Cohen's kappa coefficient ($\kappa$-value) for two categories (PGT positive either negative).  

RESULTS

PGT in leprosy patients and controls, specificity of the PGT

![Bar chart showing positivity rates for PGT1 and PGT2 in leprosy and non-leprosy patients.](image)

Fig. 1. positive PGT1 of the great toes and PGT2 of the lesser toes in leprosy patients and non-leprosy controls. Numbers in the columns present absolute amounts of persons.

Figure 1 shows that 35.9% of the leprosy patients (n=496) had a positive PGT1 and 49.6% a positive PGT2 of one or both great toes. In comparison, in the control group (n=170), 7.1% had a positive PGT1 and 17.6% a positive PGT2 of one or both great toes. Corrected for gender and age, significantly more leprosy patients than non-leprosy controls had a positive test ($pcc=0.29$ and $p<0.01$ for both PGT1 and PGT2). Positive tests in the control group can be regarded as false positive tests, so from these results specificity can be calculated. Sixteen (2x4 + 8) false positive results in 340 tested feet give a specificity of 95.3% for PGT1, and 47 (2x17 + 13) false positive results in 340 tested feet give a specificity of 86.2% for PGT2.

Influence of sensory loss, gender, age and leprosy type on the outcome of the PGT

To examine the relation between a positive PGT and loss of foot sole sensibility all feet of leprosy-affected people were regarded separately. These were divided into three groups according to the degree of sensibility loss of the foot sole.
Figure 2 shows that 71.3% of the total anaesthetic feet had a positive PGT of both great and lesser toes (positive PGT1 and PGT2). In the group of partial anaesthetic feet 33.2% had a positive PGT1 and PGT2, while 25.6% showed either PGT1 or PGT2 positive. Leprosy feet with a normal sensibility showed a positive PGT1 and/or PGT2 in 24.8%. The relation between degree of sensibility loss and a positive PGT proves to be significantly correlated after correction for gender, age and type of leprosy (pcc= 0.49, p<0.01).
Fig. 3. Intrinsic muscle weakness of the great toes in males and females in both leprosy patients (N=496) and non-leprosy controls (N=170). Numbers in the columns present absolute amount of persons.

The presentation of a positive PGT test among males and females in both leprosy and non-leprosy groups is shown in figure 3. Female leprosy patients turned out to have a higher prevalence of a positive PGT of one or both great toes (46.0%) than male leprosy patients (31.0%). After correction for age and type of leprosy this relation proved to be significant (pcc= 0.21, p<0.01). In the non-leprosy group these values were 14.0% for females and 3.5% for males (pcc= 0.24, p<0.01).
Fig. 4. positive PGT1 of the great toes in different age groups in leprosy patients and non-leprosy controls. Numbers in the columns present absolute amounts of persons.

Figure 4 shows that the prevalence of a positive PGT increases with older age. PGT1 was positive in 49.5% of leprosy patients in the age group 40 – 59, against 21.0% positive tests in the age group up to 19. After correction for gender and type of leprosy the relation between a positive PGT1 and age proves to be significant for both leprosy group (pcc= 0.22, p<0.01) and control group (pcc=0.19, p=0.01).
Fig. 5. positive PGT1 of the great toes in different types of leprosy. Numbers in the columns present absolute amounts of persons.

The distribution of a positive PGT among different types of leprosy is shown in figure 5. The percentages of patients with positive PGT1 of one or both feet varies significantly per type of leprosy after correction for gender and age (pcc=0.16, p<0.01). The highest percentages of a positive PGT were found among patients with PN, BB and LL type of leprosy. A positive PGT1 in TT type of leprosy (14.3%) is two times higher than in non-leprosy patients (7.1%, fig.1).

**Validity and reliability of the Paper Grip Test**

In both leprosy patients and non-leprosy subjects the PGT1 changed from negative (normal) to positive (abnormal) in all 14 feet tested, after blocking the tibial nerve inside the tarsal tunnel with 5cc bupivacaine 1%. The long flexors of the foot and toes remained unaffected.

Electromyography in three healthy persons confirmed that the plantar intrinsic muscles were used in testing with the PGT. However, also long flexors of foot and toes showed electromyographic activity.

The e-value for the inter-observer reliability (non-weighted, 2 categories, n= 40 feet) is calculated at 0.87 [95% CI: 0.69-1.04] for PGT1 and 0.61 [95% CI: 0.34-0.87] for PGT2. The e-value for the intra-observer reliability (non-weighted, 2 categories, n= 86 feet) is calculated at 0.56 [95% CI: 0.36-0.76] for both PGT1 and 0.56 [95% CI: 0.39-0.74] for PGT2.
DISCUSSION

Validity, specificity and reliability of the PGT
The results of the experiment, before and after the block of the tibial nerve at the level of the tarsal tunnel (unaffecting the long flexors and extensors of foot and toes), show that the PGT1 is capable to selectively demonstrate intrinsic foot muscle weakness. The EMG experiment shows that also extrinsic muscles were activated during the PGT but by assuring normal strength of the long flexors in all our subjects there was no difference between our subjects regarding extrinsic muscle function.

The specificity of 95.3% for PGT1 found in this study can be considered as high compared to that of other manual muscle strength tests.16 There is a lower specificity of PGT2 (86.2%) than PGT1. To prevent many false positive results the PGT1 is probably a better screening method to detect intrinsic muscle weakness than the PGT2. However, the two tests do not provide identical information, so another possibility, explaining the higher percentages of positive PGT2 than PGT1 in the leprosy group, is that the lateral plantar nerve is more often affected by leprosy than the medial plantar nerve.

The inter-observer agreement can be regarded as good for PGT1 and moderate/good for the PGT2. This is comparable to the intertester reliability of other manual muscle strength testing used in leprosy9, but the number of patients was small. The intra-observer reliability is moderate for both PGT1 and PGT2.2 When the moderate $\kappa$ value really reflects the intra-reliability of the PGT, this is a relative weakness of the PGT. However, the moderate reproducibility may also be caused by actual changes in muscle function during the long interval between the first and second measurement (about three months). Especially in the beginning phase of multidrug therapy nerve reactions that cause changes in muscle function may occur.

The correlation that we found between both age and type of leprosy and positive PGT's is similar to the correlation between several disabilities, based on peripheral nerves affection, and age and type of leprosy described in other studies.10,18

The use of the PGT as a screening test for intrinsic muscle paralysis of the foot
The PGT can be a valuable addition to the physical examination of leprosy outpatients. It is a simple, cheap and non-invasive test that does not require additional equipment. These properties make the test especially suitable for screening on the function of plantar intrinsic foot muscles in leprosy patients in hospitals and during fieldwork in developing countries. From our results we conclude that screening of leprosy patients with PGT’s additional to sensibility testing is very important. Firstly, because we found that the intrinsic muscles of the great toe are affected in more than one-third of the leprosy patients without gross deformities. Secondly, because many partially anaesthetic feet appeared to have intrinsic muscle weakness. Thirdly, in this study intrinsic muscle weakness of both great and lesser toes is found in more than 70% of the total anaesthetic feet, making them especially vulnerable to ulceration. On the other hand, 15% of the patients with total anaesthetic feet has strong intrinsic muscles making them less vulnerable to ulceration.24 The care of these patients in
the long-term could be limited to regular control of the skin of the foot and the use of protective footwear. Late development of plantar paralysis long after cure of the disease is quite rare. Fourthly, because the PGT may give early warning of nerve function impairment in patients with intact foot sole sensibility measured by a 10 grams monofilament method.

**Clinical consequences of a positive PGT- prevention of foot deformity**

When impaired intrinsic muscle function of the foot is detected by means of the PGT screening method, this has important clinical consequences. An early sign of loss of intrinsic muscle function deserves the same treatment as for instance signs of ulnar nerve neuritis. Apart from the attempt to treat the neuritis e.g. with corticosteroids, other measures to prevent deformity of the foot are necessary. When a patient has a positive PGT, a Harris mat print can be used, if available, to detect changes in the weight bearing areas⁹ as an indication to adapt the footwear. Special protection of especially the metatarsal area can be created by e.g. the provision of a rigid sole, which will prevent stress to the metatarsal pads during the push-off phase of walking. In a flat terrain also a rocker mechanism can be considered. The insole should provide support to the longitudinal arch by an arch-support, to the transverse arch and the metatarsal heads by a metatarsal button, and add stability to the heel by a heel cup. Signs of collapse of the longitudinal arch can be detected by measuring a decreasing projection height of the medial malleolus of the weight bearing foot. In an early stage of claw toes, when the toes are still mobile, a tendon transfer is possible to prevent further clawing of the toes.¹³

**Limitations of the PGT and recommendations for improvement**

The lack of another reliable, non-invasive clinical test that measures intrinsic muscle strength with which the PGT could be compared, is a limitation of this research. Because we could not compare the PGT to another test, it was not possible to assess the sensitivity of the PGT. The only reliable gold standard would be needle electromyography, which we did not use in this study. Surface electromyography showed not only electromyographic activity in the intrinsic muscles but also in the long muscles of the toes. But, by assuring normal strength of the long flexors in all our subjects, a positive PGT caused by weak extrinsic muscles is excluded.

The first examiner performed the inclusion of patients and PGTs so the outcome of the PGTs was potentially vulnerable to information bias due to knowledge of variables as leprosy/non-leprosy and type of leprosy. During examination of the foot this examiner also became aware of ulcerations of the foot. This bias was limited by emphasising to all subjects to give as much pressure to the paper slice as they could.

False positive PGT’s may be caused by generally small muscle power and/or persons’ misunderstanding of the test procedure. This may also explain the higher percentages of positive PGT’s in older people and females in both leprosy and control groups. Moreover, females were less inclined to give firm resistance with their feet in reaction to the pulling of the paper.
A relatively high proportion of feet of leprosy-affected persons with no loss of plantar sensibility was found to have positive PGTs (PGT1 10.7%, PGT2 23.1%). Partially this could be explained by false positive results of the PGTs, but in the control group the proportions of positive PGTs are significantly lower. This could probably be explained by the relatively low sensitivity of the 10 grams monofilament sensibility test for mild sensibility loss of the footsole. More sensitive sensibility testing, with a 2 grams monofilament for example, should be performed in these patients. Also, sensibility was regarded as normal when a patient was able to indicate all three regions of pressure stimulus with closed eyes at least one out of three times. This will not eliminate some errors due to guessing so this could have lead to underestimation of sensibility loss in the leprosy group.

The exclusion of patients with foot deformities gives an underestimation of the percentage of leprosy patients with intrinsic muscle weakness. It is likely that the majority of them has paralysis of intrinsic foot muscles.

The influence of the use of different types of paper slips and different types of underground is not investigated in our study. When the paper slip used is too thin, the tearing point of the paper will become critical to identifying the threshold for a negative test. Therefore we recommend standardisation of the paper quality and paper size. We would advise the size and type that is used for business cards (at least 100 g/m²), as this paper will not easily tear and is widely available. Also the direction and rate of force, the area the force is applied to the paper and testing surface could probably influence the outcome of the PGT. We recommend standardisation of these as a further objective of study.

It would also be interesting to correlate the PGT results with additional variables such as presence of ulcer/scar at certain sites and site of anaesthesia to increase the validity of the PGT.

SUMMARY

Plantar intrinsic foot muscles provide structure to the foot during walking and thus regulate mechanical foot sole stresses. When paralysed, for instance in leprosy patients with neuropathy of the distal part of the tibial nerve, there is a high prevalence of plantar ulceration and deformities, especially when muscle weakness goes together with loss of foot sole sensibility. These patients should get immediate care involving education, special footwear and reconstructive surgery before further foot impairment and deformity become manifest. Thus far, in leprosy patients little attention is paid to screening of plantar intrinsic muscles activity. This can be done with a new simple and non-invasive method, the Paper Grip Test (PGT). There are two variants for detecting intrinsic muscle weakness of the foot, PGT1 for the great toe and PGT2 for the combined lesser toes.

In this study, 517 leprosy patients and 170 healthy volunteers were investigated with the PGT. Sensibility of the foot sole was tested by means of a 10 grams monofilament. Specificity of the PGT1 is found to be about 95.3%, which is good for physical diagnostic tests. PGT2 is less specific than PGT1. Individual muscle power and understanding of the
patient seems to influence the outcome of the test to a certain extent. Sensitivity can only be calculated when the diagnosis is confirmed by electromyography. Especially patients with anaesthetic feet, females, older patients and patients with PN, BB or LL types of leprosy appeared to have a higher prevalence of intrinsic foot muscle weakness. All results were analysed by means of the bivariate Pearson correlation-analysis and proved to be statistically significant (p<0.05). It is concluded that the PGT1, more than the PGT2, is a useful screening test on the function of plantar intrinsic foot muscles in leprosy patients in hospitals and during fieldwork in developing countries.

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