

Relationship between Hallux Limitus and Ulceration of the Great Toe

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Torque range of motion (TROM) measurements of the metatarsophalangeal joint (MTPJ) of the great toe were made to determine the relationship of joint stiffness and plantar ulceration. Subjects included 20 patients with a history of plantar ulceration of the great toe (GTU), 20 patients with a history of ulceration on the plantar surface of the foot excluding the great toe (NGTU), and 20 normal controls. Peak MTPJ extension was significantly reduced in the GTU group compared to NGTU and control groups ($p < 0.0001$). The slopes of the TROM and stiffness curves were significantly steeper ($p < 0.0001$) in the GTU group compared to the control group ($p < 0.0001$). Results support the hypothesis that stiffness is a factor in plantar ulceration of the great toe.

Plantar ulceration is a common complication of the neuropathic foot, usually caused by repetitive stress on the foot during walking.^{2,3,10} Rat foot pads subjected to repetitive stress have shown sequelae of inflammation, necrosis and ulceration.² Ctercteko et al.⁶ found that in diabetic patients, plantar ulcers occurred at the site of maximum loading. Lang-Stevenson et al.¹² and Ctercteko et al.⁶ concluded from separate studies on neuropathic plantar ulcers that static or dynamic deformity may result in localized areas of high force on insensitive skin. Srinivasan¹⁴ reported the most common site for plantar ulcers in 232 Hansen's disease patients was on the plantar surface of the great toe with 34% of the total number of ulcers, and 48% of the total number of affected feet.

Hallux limitus (HL), also referred to as hallux rigidus, is a structural foot deformity resulting in limitation of dorsiflexion of the metatarsophalangeal joint (MTPJ) of the great toe. The etiology of HL includes osteochondritis dissecans, arthritis, trauma, metatarsus elevatus, foot shape, and other factors.⁷ Gould⁹ reported from a 1978–1979

survey in the United States, the incidence of HL in persons 31 to 60 years of age was 1 in 60 for whites and 1 in 100 for blacks. The male-female ratio was 8 to 1. There is also considerable variation in normal range of motion (ROM) for any joint. The range of motion of the great toe was measured radiographically in 50 male subjects by Joseph.¹¹ Using the dorsal aspect of the first metatarsal and the shaft of the proximal phalanx as axes, he reported 16.2° of MTPJ dorsiflexion in the neutral position (standing) of the foot, 50.6° of active MTPJ dorsiflexion, and 73.2° of passive MTPJ dorsiflexion. If passive ROM was measured from a 0° neutral position, mean MTPJ dorsiflexion would be 57°. A minimum of 45° MTPJ extension is required for walking.⁸

In a study of 25 diabetic patients, Barrett and Mooney¹ found that each of the 5 patients with great toe ulcers had hallux rigidus. It is believed that limitation of toe extension results in greater plantar pressure during the propulsive phase of gait, predisposing the great toe to ulceration.

Torque range of motion (TROM) is a noninvasive technique for assessing resistance to movement at a joint. Increasing amounts of force or torque are applied to a joint and the angular change in the joint is related to the change in length of the tissues around the joint.⁴ TROM has been shown to be an effective and objective method of analyzing joint stiffness.¹⁶ Torque or force angle curves are plotted as the degrees of motion at the joint for increasing amounts of torque applied to the joint. The torque angle curve

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may provide information on the characteristics of the tissue contributing to the joint stiffness.⁴

The purpose of this study was to determine the relationship between the range of metatarsophalangeal extension and great toe ulceration in subjects with insensitive feet. If HL is an etiological factor in ulceration of the great toe, it is expected that patients with a history of great toe ulceration will have significantly less MTPJ extension than patients who have a history of ulceration at other sites of the foot and normal subjects. The results of this study may provide a basis for developing improved methods of prevention and treatment of great toe ulcerations.

METHOD

Subjects

Three groups of 20 subjects each participated in this study. A control group consisted of 20 normal subjects (10 males, 10 females) with no sensory loss or symptomatic conditions of the foot. The left foot was used for all measurement in the control group. The experimental groups consisted of subjects with a history of neuropathic ulcers, 29 with a diagnosis of Hansen's disease, 9 with a history of diabetes mellitus, and 2 with other diagnoses of peripheral neuropathy. Twenty subjects (15 males, 5 females) with a history of ulceration of the plantar surface of the great toe were assigned to the first experimental group. The other experimental group consisted of 20 subjects (12 males, 8 females) with a history of plantar ulceration excluding the great toe (NGTU). The mean age was 50.5, 56.5, and 58.0 years for the control, NGTU, and GTU groups, respectively.

Instrumentation

TROM values were obtained using an electrogoniometer (ELGON, Rehabilitation Research Dept., Gillis W. Long Hansen's Disease Center, Carville, LA 70721) strain gauge, and microcomputer. Torque was applied to the toe (Fig. 1) in the direction of extension utilizing a cantilever beam type strain gauge developed at the Gillis W. Long Hansen's Disease Center. A 1/8 inch diameter loop of cotton string was attached at a 90° angle to the end of the strain gauge beam. The diameter of the string was chosen by experimentation to reduce the applied force to a small area, without creating potentially damaging forces.⁴ ROM was measured by a "rabbit ear" type ELGON, modeled after a system developed by Cantrell and Fisher.⁵ It consisted of two wires con-

nected on one end to a 360° goniometer. The unattached ends of the wires were adapted with aquaplast to be placed on the proximal phalanx of the great toe and on the dorsal aspect of the first metatarsal. Velcro straps secured the wires to the patient's foot. Force and ROM data were recorded as voltages on a microcomputer utilizing an analog to digital converter. (Digital 340 PC, Professional 350 Digital Equipment Corp., Nashua, NH). ROM was recorded at each of the following force values: 300, 600, 900, 1200, 1500, 1800, 2100, 2400, and 2700 g. A plot of the obtained ROM at each force constituted the TROM curve.

Procedure

TROM for passive extension of the MTPJ of the great toe was performed on all subjects. Each subject was positioned supine on a padded plinth. A mark was made 4.5 cm distal from the MTP joint line to indicate the placement of the strain gauge. This distance was chosen as an optimal standardized lever arm of force within the variation of anatomical toe lengths for all subjects. The two arms of the ELGON were securely fastened on the proximal phalanx of the great toe and on the first metatarsal with velcro straps. A plastic ankle foot orthosis was placed on the subject to maintain the ankle at 90°. The MTPJ was held in a position of 0° of dorsiflexion while the ELGON was reset to 0° for each subject. If joint contractures were present 0° of dorsiflexion was estimated. Each subject was instructed to relax the foot during the test session. The loop of cotton string from the strain gauge was positioned on the great toe at a point 4.5 cm distal to the MTPJ line. The examiner applied a force perpendicular to the long axis of the great toe from 0 to 2700 g. This procedure was demonstrated once, prior to obtaining three experimental trials for each subject. The amount of extension at each predetermined level of force was stored in the computer for later analysis.

Data Analysis

The mean of the three trials of TROM for each subject was used for analysis. Force angle and joint stiffness curves were plotted for each group (Figs. 2 and 3). Joint stiffness was determined by the following formula: Joint stiffness = change in angle/change in force. Linear regression coefficients were calculated for the first half (300–1500 g) and the second half (1500–2700 g) of the force angle curves. These values were termed slope 1



Fig. 1. Method of performing torque range of motion measurements using a "rabbit ear" electrogoniometer and cantilever beam type strain gauge.

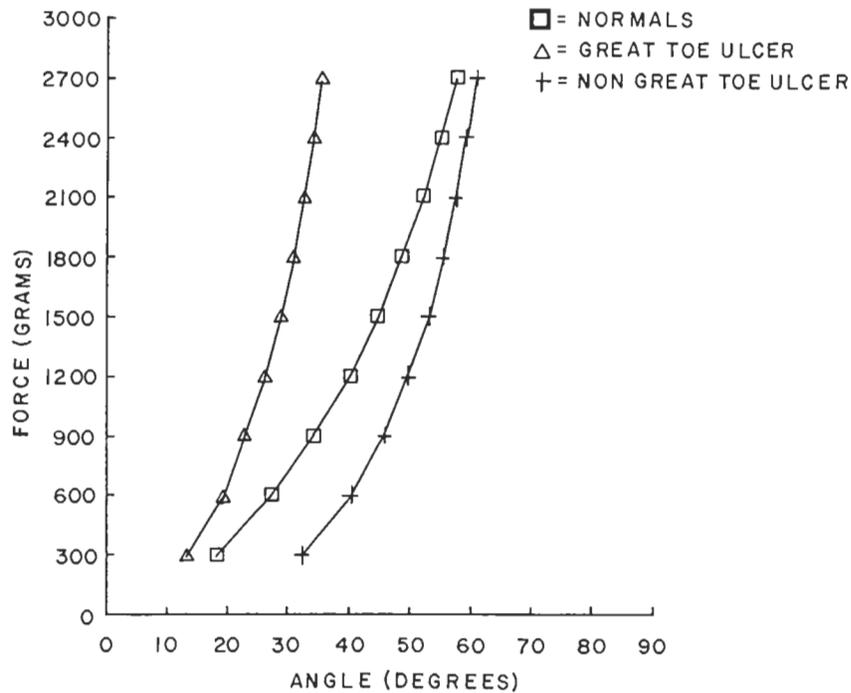


Fig. 2. Force angle curves for treatment groups.

and slope 2. Measurements of peak MTPJ extension, total MTPJ extension were also determined for all groups. An intraclass correlation (ICC) was performed on the three repeated measurements of peak MTPJ extension to determine the reliability of the testing procedure. Analysis of variance tests (ANOVA) were used to determine if there were significant differences among the three groups. A Scheffe's multiple comparison test was then performed to determine which groups dif-

fered. A significance level of 0.05 was used for all comparisons.

RESULTS

The ICC for three repeated peak MTPJ extensions was 0.99. Peak MTPJ extension, total ROM, slope 1 and slope 2 is presented in Table 1. The results of the ANOVA showed significant differences for peak MTPJ extension, $F(2,57) =$

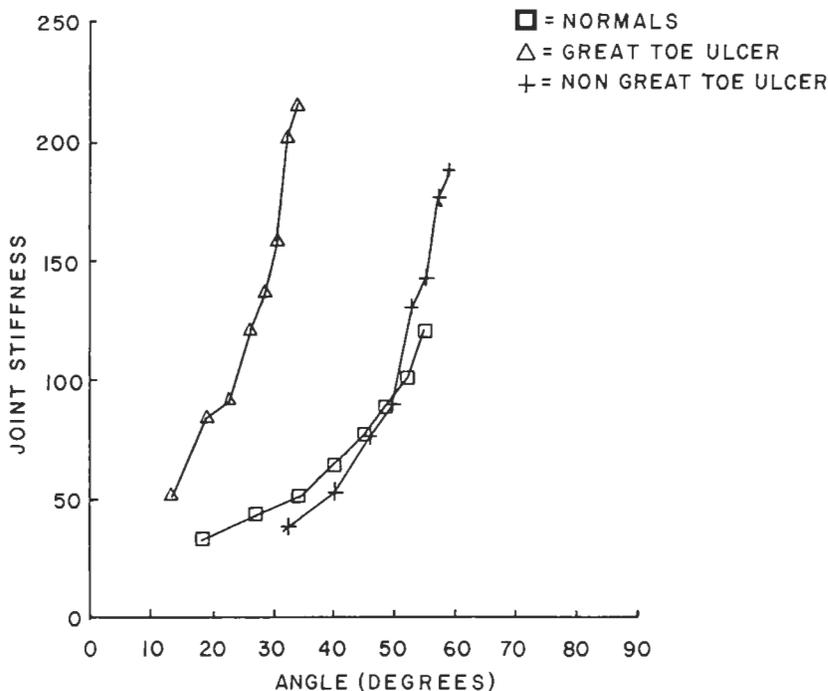


Fig. 3. Stiffness curves for treatment groups.

TABLE 1
Group means and standard deviations for first metatarsophalangeal joint extension

Groups	Peak ROM	Total ROM	Slope 1	Slope 2
GTU	35.6 (16.4)	22.3 (11.1)	98.9 (47.4)	219.7 (112.8)
NGTU	60.7 (18.9)	28.4 (10.6)	68.1 (28.5)	170.7 (50.5)
Normals	57.7 (18.3)	39.4 (12.3)	49.3 (13.4)	108.2 (43.3)

11.46, $p < 0.0001$. Post-hoc analysis showed the normal and NGTU groups were significantly greater than the GTU group.

The ANOVA was significant for total ROM, $F(2,57) = 11.54, p < 0.0001$. The Scheffe's test showed the normal group had significantly greater ROM than both the GTU and NGTU groups. No differences for total ROM, however, were found between the GTU and NGTU groups.

The ANOVA was significant for slope 1, $F(2,57) = 11.65, p < 0.0001$. The Scheffe's test showed slope 1 was significantly greater for the GTU group compared to both the NGTU and normal groups. No differences were found between the NGTU group and normals. The ANOVA was significant for slope 2, $F(2,57) = 10.92, p < 0.0001$. The Scheffe's test found slope 2 was significantly greater in both the GTU and NGTU groups compared to normals.

DISCUSSION

Results of this study provide support for the hypothesis that HL is a predisposing factor for the development of plantar great toe ulcers in ambulatory persons with insensitive feet. Age is not felt to be a confounding variable since the mean age for all groups in this study was in the fifties. The GTU group had significantly less MTPJ extension than the normal and NGTU groups, which supports the conclusion of Lang-Stevenson et al.¹² and Ctercteko et al.⁶ that static or dynamic deformity may result in localized areas of high pressure in insensitive feet. The presence of HL may put the great toe under higher pressures at the point of toe-off in gait because of the increased lever arm resulting from joint inflexibility.¹ Further research on the amount of pressure under the great toe during walking in persons with and without hallux limitus would be of interest. Other factors, such as footwear, previous treatment, or paralysis could also have contributed to the formation of great toe ulcers.

The issue of whether the MTPJ stiffness is a cause or an effect of ulceration should be considered. Toe stiffness in the GTU group may have been the direct result of the ulcer or posthealing scar formation; however, the authors believe this is unlikely because the locations of great toe lesions, in this study, were at the interphalangeal joint or distal phalanx and did not involve the

MTPJ. These locations are in agreement with the observations of other investigators.^{12,13} The GTU group may also have received treatments such as plaster casts. This would produce joint stiffness as a result of the immobilization. While possible, this explanation is unlikely since the NGTU group received similar immobilization treatment for their ulcers.

Srinivasan¹⁵ found that 97% of feet with great toe neuropathic ulcers had some degree of paralysis of the intrinsic foot muscles, and 84% had paralysis of the abductor hallucis specifically. Intrinsic muscle paralysis could be associated with the incidence of HL as well as great toe ulceration in this population.

The shape of the force angle and stiffness curves show distinct differences between the three groups (Figs. 2 and 3). The force curve for the GTU group, as well as the second half of the NGTU group, is steeper than that of the normal group. The steeper the stiffness and force angle curves, the greater would be the resistance of the great toe against the ground reaction forces during gait. While there is no significant difference between the mean peak MTP extension for the normal and NGTU groups, the force angle curves are shown to differ. The degree of MTPJ extension at the first force value of 300 g is considerably higher for the NGTU group than the normal or GTU groups. These differences are explained by the presence of extension deformity (claw toe) for many of the individuals in the NGTU group. Paralysis of the intrinsic foot muscles and claw toe deformities are common in the neuropathic foot¹⁵ and may account for the initially high amount of MTP extension found in the NGTU group. The NGTU group had similarities with both the GTU and normal group. While the stiffness in the NGTU group would predispose the great toe to greater plantar pressure, the extension deformity would reduce the forces acting on the plantar great toe during walking.

The high ICC value indicates that the TROM procedure is a reliable assessment procedure for a single testing session. Further study of the intertester reliability and test-retest reliability for separate testing days would be valuable.

CONCLUSION

These results show that there is a significant relationship between limitation of great toe MTPJ

extension and the presence of plantar great toe ulceration. The presence of hallux limitus in a patient with an insensitive foot should alert the physical therapist and other clinicians to anticipate and prevent ulceration under the great toe.

Physical therapists are frequently involved in ulcer management programs for the foot. In patients with great toe ulceration and associated hallux limitus, treatment methods should be directed at reducing the mechanical stresses created by MTPJ stiffness. In addition, posthealing footwear should be designed and monitored to ensure mechanical stresses are reduced at the toe during ambulation.

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