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0894-9115/03/8205-0345/0
American Journal of Physical Medicine & Rehabilitation

DOI: 10.1097/01.PHM.0000064718.24109.26

Research Article

Muscle Imbalance in Hallux Valgus

An Electromyographic Study

ABSTRACT

Arinci İncel N, Genç H, Erdem HR, Yorgancioglu ZR: Muscle imbalance in hallux valgus: An electromyographic study. *Am J Phys Med Rehabil* 2003;82:345–349.

Objective: Hallux valgus is a very common foot deformity in modern societies. Muscle imbalance in abductor and adductor muscles was cited as a major factor in the production of hallux valgus. Our aim in this study was to evaluate the role of certain muscles in this deformity.

Design: Twenty hallux valgus patients and 20 healthy volunteers participated in the study. After thorough physical, neurologic, and radiographic investigations, we performed an electromyographic study to observe the relationship of hallux valgus deformity with the muscles coordinating first metatarsophalangeal joint movements. Voluntary extension, flexion, abduction, and adduction at the hallux with maximum resistance were performed. Firing rates and amplitudes of motor unit potentials of four muscles: musculus abductor hallucis, musculus adductor hallucis, musculus extensor hallucis longus, and musculus flexor hallucis brevis were recorded. Statistical analysis, including Spearman's correlation analysis and Mann-Whitney *U* tests were performed with SPSS 8.0 for Windows.

Results: We observed that in the hallux valgus group, abduction activity of musculus abductor hallucis was markedly decreased when compared with adduction of musculus adductor hallucis. Motor unit potential amplitude of abductor activity recorded from musculus abductor hallucis was slightly more than half of the activity in flexion.

Conclusion: Muscle imbalance in abductor and adductor muscles is apparent in hallux valgus deformity, and this imbalance may be the reason or the result of joint deformity.

Key Words: Hallux Valgus, Foot Deformity, Muscle Imbalance, Electromyography

Hallux valgus (HV) is a very common deformity of the feet and is characterized with medial migration of the first metatarsus, valgus angulation of the first metatarsophalangeal joint, and pronation of the proximal phalanx.[1] Analysis of foot deformities require an observation including the contribution and function of anatomic structures and the evolutionary state of the foot.[2] The evolutionary changes that have affected the foot allowed the hallux to lose its prehensile function, although these changes are not yet complete. The adductor hallucis is still oriented to facilitate gripping, and the antagonistic abductor hallucis is at a mechanical disadvantage. This imbalance is considered as relevant to the cause of HV.[3] Our aim in this study was to evaluate the role of these muscles in HV deformity in the light of these data.

MATERIAL AND METHODS

A total of 20 patients (17 female and three male patients) with complaints caused by clinically diagnosed HV deformity and 20 healthy subjects (17 female and three male subjects) were selected for the study. Patients with apparent HV were randomly selected from the outpatient clinics of our hospital. History of diabetes mellitus, HV operation, neuropathy (due to alcohol, vitamin B12 deficiency, etc.), cerebrovascular problems, poliomyelitis, cerebral palsy, or inflammatory joint disease were exclusion criteria. Thorough neurologic examination of the lower limbs, including muscle testing, were performed. Vascular status of these patients were evaluated with examination of peripheral arteries, venous stasis, and varicose veins. None of these patients had any vascular or neurologic pathologies with physical examination. Twenty sex-matched control subjects were recruited from the same outpatient clinics. Inclusion criteria of the control group were asymptomatic feet with no deformities. Exclusion criteria were the same with the patient group. All radiologic examinations and electromyographic (EMG) studies were performed for both patients and the control group.

Age, sex, height, and weight of all subjects were recorded. Body mass indexes were calculated according to weight (in kilograms)/height (square meters) formula. Four muscles known to support the foot arch—musculus tibialis anterior, musculus tibialis posterior, musculus peroneus longus, and musculus peroneus brevis—were assessed with manual muscle testing.[4] For radiographic evaluation, weight-bearing anteroposterior foot radiographs were examined. HV angle was measured as the angle formed by the intersection of the longitudinal axes of the proximal phalanx and the first metatarsus.[5]

We performed an EMG study to investigate the relationship of HV deformity with the muscles coordinating first metatarsophalangeal joint movements. We used the 4 Channel EMG Navigator version 2.01, Model 996, Biological Equipment for EMG studies at the same room with temperature between 20 and 22°C. The sural nerve sensory latencies were studied to exclude the polyneuropathy cases that might be missed by physical examination, and all were normal. We used surface electrodes to record the motor unit potentials (MUPs) from four muscles—musculus abductor hallucis, musculus adductor hallucis, musculus extensor hallucis, and musculus flexor hallucis— during maximum muscle contraction. In general, active electrodes were placed on the most prominent portion of the muscle bulk, and reference electrodes were placed approximately 3 cm proximal to the active electrode. Electrode placements for the muscles are given in Table 1.[6] An earthing electrode was strapped over the lower third of the medial surface of the tibia. EMG activity was recorded with a frequency band extending from 10 to 5000 Hz, and noise was filtered by 60 Hz to suppress the stimulus artifact and stimulators causing environmental interference (fluorescence bulbs, wall plugs, etc.).[7] EMG activity was accepted as absent in a relaxed-feet stance as stated by Duranti et al.[8] in a previous study. Voluntary extension, flexion, abduction, and adduction of the hallux against maximum resistance were performed. The primary function of the muscles were tested before other movements; for example, while testing musculus abductor hallucis, abduction of the hallux was followed by adduction, extension, and

TABLE 1
Active electrode placements for electromyographic studies for the muscles observed

Muscle	Electrode Insertion
Musculus abductor hallucis	Approximately 1–2 cm posterior to the navicular tuberosity; this will be just anterior to an imaginary line drawn through the anterior margin of the medial malleolus
Musculus adductor hallucis	For the transverse head, just proximal to the third metatarsophalangeal joint, the most prominent part of the muscle belly
Musculus extensor hallucis longus	Three finger widths above the bimalleolar line of the ankle just lateral to the crest of the tibia
Musculus flexor hallucis brevis	Proximal and medial to the tendon of the flexor hallucis longus, the most prominent part of the muscle

flexion. Amplitude and interference patterns of MUPs were recorded. Recorded MUPs were grouped as full interference pattern, reduced interference pattern, and single-MUP samples according to their firing frequencies. The EMG signal called interference pattern seems complex, contains discharges of several MUPs that superimpose on one another repeatedly, and the individual MUPs can no longer be recognized. If the interference pattern contains discharges of only a few motor units, it is described as reduced or incomplete.[9,10] If a reduced interference pattern is seen on the screen, one could assume that there is a substantial degree of weakness present.[9]

Statistical analysis were performed with SPSS 8.0 for Windows (SPSS, Chicago, IL). Variables were correlated by means of Spearman's correlation analysis. Results of EMG analysis of patient and control groups were compared with Mann-Whitney *U* test. *P* values of ≤ 0.05 were considered to be significant.

RESULTS

The HV group consisted of 17 female and three male subjects who ranged in age from 25 to 70 yr (mean ± SD, 45 ± 12 yr). Our control group also included 17 female and three male volunteers, with ages ranging between 26 and 67 yr (mean ± SD, 44 ± 13 yr). There was no statistically significant difference for age, sex, height, weight, and body mass indexes between study groups. Measurements of HV angle revealed significant differences between groups. In the HV group, three patients had mild HV (HV angle of <20 degrees), 16 had moderate HV (HV angle between 20 and 40 degrees), and one had serious HV (HV angle of >40 degrees). HV angle ranged between 18 and 55 degrees in HV patients (mean, 24.85 ± 8.59 degrees) and ranged between 3 and 11 degrees (mean, 8.05 ± 3.02 degrees) for the control group.

The study population all had normal sural nerve latencies. Mean MUP amplitude values recorded from the four muscles during four different movements for patient and control groups are given in Table 2.

All amplitude values were higher for the control group, compared with the patient group. Flexion activity of flexor hallucis had revealed maximum amplitude values obtained from both groups. There was a statistically significant difference (Mann-Whitney *U* test) between amplitudes of abduction of abductor hallucis and adduction of adductor hallucis muscles between patient and control groups ($P < 0.001$ and $P < 0.01$, respectively). The mean MUP amplitude value of abduction activity recorded at abductor hallucis for our control group was nearly twice the HV group. For the HV group, abduction and flexion of abductor hallucis longus were observed, and MUP amplitudes of abduction activity was slightly more than half of the MUPs in flexion. An interesting finding was that there was no significant difference between MUP amplitudes of two groups recorded during flexion of flexor muscles (Fig. 1).

For all movements and muscles examined, amplitude and firing rates of MUPs were well correlated. MUP interference patterns were also compared between study groups, and the abductor hallucis muscle showed a significant difference for maximum voluntary abduction: in the HV group, six patients had single-MUP samples, 13 had a reduced interference pattern, and only one patient had a full interference pattern, whereas for the control group, six reduced interference patterns and 14 full interference patterns were recorded, with no single-MUP samples. MUP patterns recorded from flexion movement of abductor hallucis and flexor hallucis and adduction of ad-

TABLE 2
Mean values for amplitudes of motor unit potentials recorded during four different movements

Muscle	Abduction	Adduction	Flexion	Extension
Hallux valgus group				
Musculus abductor hallucis	498 ± 280	45 ± 69	973 ± 349	220 ± 379
Musculus adductor hallucis	5 ± 22	312.5 ± 128	170 ± 113	88 ± 51
Musculus flexor hallucis brevis	315 ± 300	217.5 ± 186	1105 ± 450	50 ± 76
Musculus extensor hallucis longus	185 ± 153	285 ± 221	0 ± 0	828 ± 353
Control group				
Musculus abductor hallucis	980 ± 456	70 ± 130	773 ± 529	348 ± 570
Musculus adductor hallucis	40 ± 82	435 ± 88	195 ± 119	95 ± 100
Musculus flexor hallucis brevis	490 ± 321	180 ± 217	1148 ± 489	30 ± 73
Musculus extensor hallucis longus	265 ± 146	230 ± 113	40 ± 68	683 ± 262

Values are in microvolts, presented as mean ± SD.

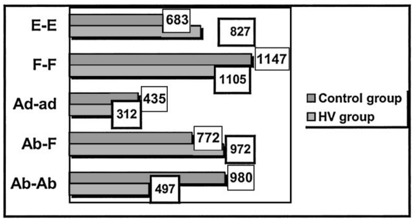

Figure 1: Comparison of mean motor unit potential amplitude values recorded from muscles during activities of hallux. *E-E*, extension of musculus extensor hallucis longus; *F-F*, flexion of musculus flexor hallucis brevis; *Ad-Ad*, adduction of musculus adductor hallucis; *Ab-F*, flexion of musculus abductor hallucis; *Ab-Ab*, abduction of musculus abductor hallucis; *HV*, hallux valgus.

ductor hallucis activity did not show significant difference between the two groups ($P > 0.05$).

DISCUSSION

EMG studies helped us to identify the role of muscles in HV deformity, as abductor-adductor muscle imbalance is cited as a major factor in the development of HV deformity.[3,11] In a previous study, Hoffmeyer et al.[3] performed muscle biopsies for 57 HV patients and reported that in 53 biopsy specimens, the muscles were found to be histologically abnormal. They stated that the surface EMG activity of the abductor and interosseous muscles also were abnormal. These results are in concordance with Iıda et al.[11] They also reported that in HV patients, abductor and adductor hallucis muscles have maximum activity during flexion.[12] In our study, for abductor hallucis muscle, MUP amplitudes recorded at abduction were nearly half of the ones recorded at flexion. This imbalance may be secondary to some mechanical changes. With malalignment of the bones, the distance between origin and insertion of the muscles is increased, the insertion of the adductor hallucis moves toward the medioplantar side, and the tendons of flexor hallucis are displayed laterally. As a result, the adductor hallucis and flexor hallucis brevis are stretched with the adductor losing its force markedly. The tendon of the abductor hallucis moves toward the plantar in relation to the metatarsal head, so it completely loses its abductor force instead of gaining flexor force.[3]

Normally at the metatarsophalangeal joint, abductor and adductor forces are balanced. However, in HV, although the adductor force is decreased, the abductor force is mostly lost and the weak adductor force becomes dominant. These statements are supported by the observations of Thomson and Coughlin[12] for hallux varus treatment. Iıda et al.[11] found that activity of adductor hallucis in HV feet is decreased. In our HV group, MUP amplitudes recorded from adductor hallucis were also markedly low. The reduced MUP amplitudes may be due to muscle fatigue but also can be explained by the deep insertion of adductor hallucis muscle recorded by surface electrodes. Fine-wire electrodes are superior to surface electrodes, with the ability to directly reach deep muscles. Surface electrodes do not allow us to detect the precise location of the active muscle. We performed our study by placing surface electrodes to key points accepted in EMG guides and by testing all movements of the joint for each muscle.[6] These electrodes do not allow us to detect the precise location of the active muscle. We preferred surface electrodes in our patients to minimize discomfort. The general advantage of all surface electrodes is that they can be secured simply to the patient's skin with tape or in a self retaining manner with little or no discomfort. A major disadvantage of surface electrodes is that the skin offers a considerable resistant barrier, lessening the biological signal's ability to reach the recording electrode.[7]

Incidentally, we noticed that it was not easy for the HV patients to perform abduction and adduction movements at their hallux on demand. In normal feet, because of the slight obliquity of the metatarsophalangeal joints, the toes, including the hallux, tilt laterally on extension and medially on flexion.[1,13] We observed that most healthy subjects and HV patients cannot perform isolated abduction and adduction movements on a transverse plane. Most of the subjects failed abducting the toe away from others. This failure may be related to the decrease in the activity of the abductor and adductor muscles or to an altered function of these muscles resulting from origin and insertion changes.

Generally, intrinsic muscles of the feet and their nerves are relatively superficial and are subjected to multiple stresses and pressures from daily living. This fact may explain some EMG abnormalities.[14] The results of this study indicate that electromyographic studies can help us gain an insight about the role of muscle pathology in HV deformity. We noticed that in HV feet, abduction activity of abductor hallucis was markedly decreased when compared with adduction of adductor hallucis. Abductor hallucis gain flexor activity with structural deformities. We stated that muscle imbalance and weakness is apparent in HV patients, and this may be the result or the reason for the deformity. We may expect to stop further imbalance, especially at the beginning stage, by terms of exercise and other conventional methods, such as splinting and shoe modifications.

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Book Review

Spinal Cord Medicine by Drs. Steven Kirshblum, Denise Campagnolo, and Joel A. Delisa. Published by Lippincott Williams & Wilkins, Baltimore, MD, 2002, 620 pages, $129.00. ISBN: 078172869.

Across 39 chapters, this textbook hits the mark in providing a comprehensive overview of the field of spinal cord injury medicine. The author list includes specialists from a wide variety of medical, surgical, and allied health disciplines. The editors' effort in matching chapter topic to author is stellar; readers will benefit from the contributions of many prominent American clinicians and researchers. This allows the editors to accomplish several important goals. For topics for which peer-review literature is extensive (e.g., neurogenic bladder), expert authors guide the reader by distilling volumes of information into a manageable form, emphasizing only important and clinically useful information. This book passes an even tougher test on topics for which literature support is weak or parochial (e.g., driving assessment). The selection of experienced authors ensures that the information presented is reasonable, comprehensive, and fair. The editor's topic selection reflects the current science and practice of this subspecialty, heavily weighted toward traumatic spinal cord injury. Other medical conditions producing similar deficits and disabilities receive a level of attention that is generally proportionate to their importance in current clinical practice and to the existing measure of scientific information. As with most large textbooks with multiple editors and authors, chapters vary in level of detail, quality, and readability, but the quality of the literature references is uniformly excellent. I found the chapters on psychological adaptation and vocational aspects of spinal cord injury to be unique, useful, and thought provoking. I will stop there, because it is difficult, and definitely unfair, to single out individual contributions, as there are so many superb chapters. This book will be very useful as a clinical resource for physicians-in-training and practitioners who occasionally treat persons with spinal cord injury and as a reference text for those who treat these patients on a full-time basis.

Book Rating: ★★★★

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