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Brazilian Society of Foot Surgery
Belgian Society of Medicine and Surgery of the Foot
Israel Orthopaedic Foot and Ankle Society
New Zealand Orthopaedic Foot & Ankle Society
South African Foot Surgeons Association
Spanish Society of Medicine and Surgery of the Foot
Turkish Society of Orthopaedic Surgery and Traumatology
Canadian Orthopaedic Foot and Ankle Society
Taiwanese Orthopaedic Foot and Ankle Society

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Positive Hindfoot Valgus and Osteoarthritis of the First Metatarsophalangeal Joint

Melissa Y. Mahiquez, B.S.; Frances V. Wilder, Ph.D.; Heidi M. Stephens, M.D.

Clearwater, FL

ABSTRACT

Background: The aim of this retrospective cohort study was to evaluate the association between increased hindfoot valgus and the subsequent development of osteoarthritis of the first metatarsophalangeal (MTP) joint. Specifically, our hypothesis was that among individuals free from first MTP joint osteoarthritis, those who have positive hindfoot valgus are more likely to develop first MTP joint osteoarthritis than are those individuals with normal hindfoot alignment. Methods: Our sample consisted of 1592 men and women, 40 years of age or older, participating in the Clearwater Osteoarthritis Study (1988 to 2001). Biennial physical examinations, including serial radiographs, were conducted. The Kellgren and Lawrence ordinal scale was used to determine radiographic evidence (grades 2+) of the study outcomes and incidence of first MTP joint osteoarthritis. Standing hindfoot valgus was assessed visually by a registered nurse, with a hindfoot valgus measurement of more than 5 degrees classified as a positive hindfoot valgus. Results: Individuals with hindfoot valgus were 23% more likely to subsequently develop first MTP joint osteoarthritis than were those without hindfoot malalignment (risk ratio = 1.23; p-value < 0.006). This risk estimate reflects the potential influence of age, gender, and body mass index. Conclusions: Our data suggest that hindfoot valgus may increase the risk of developing foot osteoarthritis. The association of hindfoot valgus with first MTP joint osteoarthritis in this epidemiological assessment is supportive of the mechanical theory for the development of osteoarthritis. The authors speculate that future, related studies may determine that osteoarthritis prevention strategies can be broadened to include individuals with positive hindfoot valgus.

Key Words: Epidemiology; Hallux Rigidus; Hindfoot Valgus; Metatarsophalangeal Joint; Osteoarthritis

INTRODUCTION

Osteoarthritis is the most common form of arthritis, affecting more than 50 million people in the United States. By 70 years of age, most people in the United States have structural evidence of osteoarthritis on radiographs or MRI in at least one joint. Compared to osteoarthritis of the knee, hand, and hip, osteoarthritis of the first metatarsophalangeal (MTP) joint has received relatively little attention. Osteoarthritis of the first MTP joint, also known as hallux rigidus, is associated with painful dorsiflexion, progressive loss of dorsiflexion, and proliferative bony response, leading to increased bulk of the joint. Suggested predisposing factors include a long hallux, and a long, slender, or pronated foot. Our hypothesis was that positive hindfoot valgus would also be a predisposing factor to first MTP joint osteoarthritis. When the hindfoot is aligned in too much valgus, the medial border of the foot tends to roll over. This position leads to increased stress on the medial side of the first MTP joint joint, thus potentially influencing the development of hallux rigidus deformity. The foot joint most affected by osteoarthritis is the first MTP joint joint. Two studies have presented foot osteoarthritis prevalence data. Both studies used data from the 1966 National Health Survey that assessed radiographic osteoarthritis among men and women ages 18 to 79 years. Our investigation studied the hypothesis that among men and women 40 years of age or older (without first MTP joint osteoarthritis), those who have positive hindfoot valgus are more likely to develop first MTP joint osteoarthritis than those with normal hindfoot alignment.

MATERIALS AND METHODS

The Clearwater Osteoarthritis Study (COS), initiated in 1988 by the Arthritis Research Institute of America (ARIA), is an on-going community-based cohort study designed to identify major risk factors in the development and progression of osteoarthritis. Currently, in its seventeenth year,
this 25-year longitudinal study collects demographic, historical, clinical, and radiographic data. This study has been approved by an institutional review board. All participants signed informed consent. Participants received no financial compensation. Recruitment methods varied including invitation letters, television and radio announcements, newspaper articles publicizing the COS study, articles posted in community organization bulletins, as well as seminars held at community clubs and organizations. In an effort to include younger subjects who were more likely to be free of osteoarthritis, concerted recruitment efforts were used to encourage participation by employees of the Pinellas County School System, the City of Clearwater, and Pinellas County, Inc.

At baseline, the number of subjects who were free of first MTP joint osteoarthritis of either the left or right foot, or both was 1,592 out of 2969 feet. Sixty-nine percent were women (1103), while 31% were men (489). Varying from ages 40 to 91 years, the average age of all subjects combined was 62 years. The average body mass index was 26.6 kg/m² (Table 1). At baseline, the number of subjects free from first MTP joint osteoarthritis was almost identical for the left and right feet (1484 and 1485, respectively). For the left and right feet respectively, positive hindfoot valgus was identified in 36% (531) and 40% (594) of study subjects (Table 3). We categorized subjects by degrees of pronation: less than or equal to 5, 6–10, 11–15, 16–20, and more than 20 degrees. For each group, we calculated the incidence rate of first MTP joint osteoarthritis. As shown in Table 3, our data suggest that increasing baseline pronation was positively related to higher rates of first MTP joint osteoarthritis.

At the initial and all subsequent study visits, an examination (including radiographs) was conducted. Radiographs of the knees, hands, feet, and cervical spine were collected every 2 years. With an emphasis on clinical and functional joint evaluation, the examination was completed by a registered nurse. Study participants were re-evaluated every 2 years, updating both the history questionnaire and the clinical examination data. Individuals with self-reported rheumatoid arthritis or variants (i.e., lupus erythematosus, ankylosing spondylitis), gout, disabling disease, and those confined to a wheelchair or who were mentally incompetent to participate were excluded from study enrollment.

A licensed radiographic technician, using standard exposure techniques, took weightbearing radiographs. All radiographs were interpreted by a board-certified radiologist. The study outcome was osteoarthritis of the first MTP joint. A case was defined when radiographic structural evidence of disease was found. Each first MTP joint radiograph was graded 0 to 4 for osteoarthritis by the criteria of Kellgren and Lawrence (Table 3). Subjects whose radiographs were interpreted as grades 0 to 1 were categorized as disease-free for first MTP joint osteoarthritis. Subjects whose radiographs were grades 2, 3, or 4 were classified as osteoarthritis. During 1998, the interobserver variability of our institute’s radiographic interpretations was calculated using the kappa coefficient. This coefficient measures the amount of agreement between one reading and another that is above random chance. Every tenth subject’s films were interpreted by an independent radiologist who was blinded to the osteoarthritis grade of the first reading. The study radiologist and the independent radiologist were blinded to information about the individual study participants. The validation study reflected the collective films for the first MTP foot joint, as well

### Table 1: Baseline characteristics of study group N = 1592*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>% of Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female (N = 1103)</td>
<td>69%</td>
</tr>
<tr>
<td>Male (N = 489)</td>
<td>31%</td>
</tr>
<tr>
<td>Age (years)</td>
<td>61.7</td>
</tr>
<tr>
<td>Body mass index (wi/ht²)</td>
<td>26.6</td>
</tr>
</tbody>
</table>

*Subjects who were free of first metatarsophalangeal joint osteoarthritis at the left foot, right foot, or both.

### Table 2: Study sample baseline factors

<table>
<thead>
<tr>
<th></th>
<th>Left Foot</th>
<th>Right Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free of first MTP OA*</td>
<td>1484</td>
<td>1485</td>
</tr>
<tr>
<td>Positive valgus**</td>
<td>531 (36%)</td>
<td>594 (40%)</td>
</tr>
<tr>
<td>Normal valgus**</td>
<td>953 (64%)</td>
<td>891 (60%)</td>
</tr>
</tbody>
</table>

*First metatarsophalangeal joint osteoarthritis.
**0–5 degrees valgus position was categorized as normal alignment.
MTP = metatarsophalangeal joint; OA = osteoarthritis.

### Table 3: Kellgren and Lawrence osteoarthritis grading criteria

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Absent</td>
</tr>
<tr>
<td>1</td>
<td>Questionable osteophytes and no joint space narrowing</td>
</tr>
<tr>
<td>2</td>
<td>Definite osteophytes with possible joint space narrowing</td>
</tr>
<tr>
<td>3</td>
<td>Definite joint space narrowing with moderate multiple osteophytes and some sclerosis</td>
</tr>
<tr>
<td>4</td>
<td>Severe joint space narrowing with cysts, osteophytes, and sclerosis present</td>
</tr>
</tbody>
</table>
as, the joints interpreted in the hands, knees, and cervical spine. Interobserver agreement was 93% agreement (kappa = 0.85).

Right and left hindfoot alignment measurements (degrees) were recorded by the study’s registered nurse. Visual inspection determined these measurements. The valgus angle was determined with weight distributed between the legs. Sitting in front of the standing subject, the nurse evaluated ankle pronation. If this view indicated a need for further inspection, the subject turned around, facilitating pronation assessment from the back. From 1988 through 2001, these measurements were recorded by the same nurse. To eliminate the potential for inter-reader variability, we limited our current analyses to these years. A measurement of 5 degrees or less was considered normal hindfoot alignment. Subjects with hindfoot valgus of more than 5 degrees were categorized as having a positive hindfoot valgus. The unit of observation for this study was the hindfoot. Therefore, one subject contributed two units of observation. Typically, the unit of observation for a study is the individual study subject. However, we adopted this approach to enable the assessment of the unilateral association between malalignment and first MTP joint osteoarthritis. For example, when a subject presented at baseline with, or without, left hindfoot valgus, they were followed for the subsequent determination of left first MTP joint osteoarthritis status (Figure 1).

Our epidemiologic study is a dynamic entry cohort, thus allowing individuals to enroll at different times. Over 70% (1130) of our participants were enrolled during the years 1988 (175, 11%) 1989 (159, 10%), 1990 (414, 26%), and 1991 (382, 24%). The remaining participants (462, 29%) were enrolled between 1992 and 2001. As with most cohorts, members would leave the study because of relocation, death, or withdrawal. Thus, participants had differing lengths of study followup times (Table 4). The average study followup time was 7 years. Our study group was determined by several factors, including the number of subjects who returned for a followup examination. Figure 2 depicts the process by which our resulting sample was drawn.

![Figure 1](...)

**Table 4:** Association between baseline ankle pronation and rate of first MTP OA

<table>
<thead>
<tr>
<th>Pronation angle (degrees)</th>
<th># Incident cases</th>
<th>Followup time (years)</th>
<th>First MTP OA Rate (per 1000 person-years of followup time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 or less (1868)</td>
<td>413</td>
<td>13577</td>
<td>30.4</td>
</tr>
<tr>
<td>6—10 (700)</td>
<td>210</td>
<td>2484</td>
<td>45.8</td>
</tr>
<tr>
<td>11—15 (221)</td>
<td>73</td>
<td>1474</td>
<td>49.5</td>
</tr>
<tr>
<td>16—20 (168)</td>
<td>59</td>
<td>1027</td>
<td>57.5</td>
</tr>
<tr>
<td>&gt;20 (48)</td>
<td>14</td>
<td>315</td>
<td>44.4</td>
</tr>
</tbody>
</table>

![Figure 2](...)

**Left** | **Right**

<table>
<thead>
<tr>
<th>Free of 1st MTP OA</th>
<th>2238</th>
<th>2222</th>
</tr>
</thead>
<tbody>
<tr>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>2, or more, exams</td>
<td>1527</td>
<td>1527</td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Surgery exclusion</td>
<td>1523</td>
<td>1524</td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Missing confounder data</td>
<td>1486</td>
<td>1488</td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Enrolled post-2001</td>
<td>1484</td>
<td>1485</td>
</tr>
</tbody>
</table>

Fig. 1: Schematic of participants’ baseline and followup status.

Fig. 2: Sample group selection.

Hindfoot malalignment was the predictive factor. First MTP osteoarthritis was the outcome factor. Putative confounders for this association were considered and included...
in the adjusted analyses. Baseline age, gender, and body mass index were included in the final model. As the study participants had been observed for unequal lengths of time and some subjects’ followup time was truncated when we “pulled” the data for this analysis, proportional hazards (Cox’s) regression was employed to quantify the relationship between hindfoot valgus and first MTP joint osteoarthritis. This statistical approach afforded the ability to assess this association while simultaneously controlling the influence of extraneous factors. The period of observation was the interval between study entry time and either (1) the development of first MTP joint osteoarthritis, (2) study withdrawal, or (3) censoring (i.e. the data set was “pulled” for the current analyses). Statistical Analyses Software (SAS), Version 9.01, (SAS Institute, Inc., Cary, North Carolina) was used (specifically PROC PHREG) for the statistical analyses. Results reported for the unadjusted analyses also used Cox’s regression, with hindfoot valgus as the only independent variable in the model. All risk ratios reported within were hazard ratios. Power calculations were conducted to determine sufficiency of sample size for detecting an association of 2.0, or greater, between hindfoot valgus and first MTP joint osteoarthritis. Assuming that 25% of the normal valgus alignment subjects developed foot osteoarthritis, this study had over 90% power to detect such an association, if indeed, one existed (two-tailed; alpha = 0.05) (Epi Info™ 3.3.2, United States Department of Health and Human Services, Centers for Disease Control and Prevention, Epidemiology Program Office, Division of Public Health Surveillance and Informatics, 2004).

RESULTS

Over the study period, 364 (25%) and 404 (27%) became cases of confirmed left and right first MTP joint osteoarthritis, respectively. The unadjusted risk ratio quantified the association between hindfoot valgus and the development of first MTP joint osteoarthritis. The crude results indicated that individuals with positive hindfoot valgus were 58% more likely to develop first MTP joint osteoarthritis than are those individuals who had normal hindfoot alignment (risk ratio = 1.58; 95% C.I. 1.37 to 1.82). The final adjusted model included the co-variates age, gender, and body mass index as potential confounders. The adjusted association noted that individuals with positive hindfoot valgus were 23% more likely to develop first MTP joint osteoarthritis than individuals with normal hindfoot alignment (risk ratio = 1.23; 95% C.I. 1.06 to 1.42) (Table 5).

DISCUSSION

The results of this investigation indicate that individuals with hindfoot valgus are 23% more likely to develop first

<table>
<thead>
<tr>
<th>Factors associated with osteoarthritis</th>
<th>Risk Ratio</th>
<th>95% C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive valgus</td>
<td>1.58</td>
<td>1.37–1.82**</td>
</tr>
<tr>
<td>Positive valgus and age</td>
<td>1.28</td>
<td>1.11–1.48**</td>
</tr>
<tr>
<td>Positive valgus and gender</td>
<td>1.56</td>
<td>1.35–1.80**</td>
</tr>
<tr>
<td>Positive valgus and body mass index</td>
<td>1.52</td>
<td>1.32–1.75**</td>
</tr>
<tr>
<td>Positive valgus and age, gender, and body mass index</td>
<td>1.23</td>
<td>1.06–1.42*</td>
</tr>
</tbody>
</table>

*p-value = 0.006; **p-value < 0.0001; C.I. = Confidence interval.

MTP joint osteoarthritis than individuals with normal hindfoot valgus. This association maintained statistical significance while considering the influences of age, gender, and body mass index (p-value = 0.006). This study is consistent with previous suggestions that if the hindfoot is aligned in too much valgus, the medial border of the foot has a tendency to roll over. This position leads to increased stress on the medial side of the first MTP joint joint, thus potentially influencing the development of hallux rigidus deformity. For patients who are symptomatic or found to have extreme hindfoot valgus, the authors suggest that orthotic correction may help to slow the progression of first MTP joint osteoarthritis.

Approximately 32% (509) of the study group was considered lost to followup as they did not return for at least one post-baseline examination. Differences by selected characteristics between volunteers who were lost to followup and those who were not lost were examined for possible differences (Table 6). While we cannot definitively rule out potential bias, only minor differences were noted between the two groups. While a goniometer can afford future studies enhanced accuracy, we believe that our visual examination of pronation (yes/no) provided an adequate assessment.
However, if we were investigating whether 5 degrees of pronation was statistically significantly different from 10 or 15 or more than 20 degrees as a risk factor for the subsequent development of first MTP joint osteoarthritis, then visual assessment of the exposure (degree of pronation) would be inadequate.

As the “baby-boomer” cohort enters its golden years, osteoarthritis is receiving a burgeoning level of interest. The first MTP joint, however, is a weightbearing site that has received little attention in the epidemiological research on osteoarthritis. Our data suggest that hindfoot valgus may increase the risk of developing foot osteoarthritis. We suggest that the use of orthoses as soon as hindfoot valgus is noted may help to prevent or slow the progression of first MTP joint osteoarthritis. When a patient pronates the foot, weight shifts to the medial forefoot and the first ray. We know that in patients who have bunions corrected and those with pronated feet experience increased recurrence of bunions from the increased stress in the first ray. We suggest that with correction of pronation by orthoses, forefoot pressures can be shifted laterally off of the first ray area. Orthoses relieve stress from compromised joints, ligaments, and muscles. Deforming forces acting on the foot are diminished, thus likely reducing the chance of developing osteoarthritis. This information can assist clinicians in preventing or delaying the need for operative treatment, such as a cheilectomy or arthrodesis. Future studies that assess hindfoot malalignment, with a highly-specific measurement method will make a further contribution to the existing literature.

REFERENCES