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Examination of Reference Values for Flatfoot, Splayfoot, and Hallux Valgus Using Morphometric Measurements Without X-rays

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Abstract

Because therapists other than physicians are unable to use X-rays, other methods are necessary to evaluate flatfoot, splayfoot, and hallux valgus.

This study aimed to clarify diagnostic criteria for flatfeet, splayfoot, and hallux valgus by using morphometry and footprints to evaluate the medial longitudinal arch, transverse arch, and hallux valgus angle, and to investigate correlations with X-rays.

The subjects were men and women who had been diagnosed with flatfoot, splayfoot, or hallux valgus by a physician.

For flatfeet, the longitudinal arch height ratio was used, calculated by dividing the distance from the floor to the navicular bone by foot length and multiplying the result by 100.

For splayfoot, the splay ratio was used, calculated by dividing the foot width, which is the line connecting the first and fifth metatarsal heads, by actual foot length.

For hallux valgus, the hallux valgus angle was measured using footprints.

As a result, all measurement methods showed a high correlation with X-rays, and it was possible to make an assessment using reference values for flatfeet, splayfoot, and hallux valgus, even without using X-rays.

For flatfeet, the borderline longitudinal arch height ratio value is 16.4% in men and 14.6% in women, and values lower than this are flat foot.

For splayfoot, the borderline splay ratio is 40.9%, and values higher than this are splayfoot.

For hallux valgus, the borderline hallux valgus angle on the footprint is 16 degrees, and values more than this are hallux valgus.

Therefore, the diagnostic reference values for flatfoot, splayfoot, and hallux valgus were clearly defined.

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Introduction

Currently, flat foot, splayed foot, and hallux valgus are evaluated using X-rays to ensure an accurate diagnosis. However, because therapists other than physicians are unable to use X-rays, a different method is required to evaluate flat foot, splayed foot, and hallux valgus [1].

We use morphometry and footprints to evaluate the foot.

Morphometry involves measuring the height from the floor to the navicular bone and foot width, while footprints are a simple way to evaluate hallux valgus, arch condition, plantar pressure, floating toes, etc.

Unlike X-rays, they impose less of a burden on patients in terms of radiation exposure and financial burden. In this study, we used morphometry and footprints to evaluate the medial longitudinal arch, transverse arch, and hallux valgus angle, and investigated correlations with X-rays, with the aim of clarifying diagnostic criteria for flat feet, splayed foot, and hallux valgus without X-rays.

Morphometric and footprint reference values

For morphometry and footprint measurements, the limb position is set so that in the frontal plane, a line drawn from the left and right acromions is positioned on the outer edge of the foot. In the sagittal plane, the foot facing the direction of travel takes a step forward, and the rear foot is measured. The stride length should be set to 45% of height, and the ankle joint dorsiflexion angle of the rear foot should be set to 5°[2]. In the horizontal plane, the toes (line connecting the second toe and the center of the heel) should be pointed in the direction of travel, perpendicular to the line connecting the left and right anterior superior iliac crests.

Standard values for flatfoot

Subject

The study included 28 feet of 18 patients, consisting of 15 feet of 9 men and 13 feet of 9 women, who had been diagnosed with flat feet by a doctor based on the condition of the medial arch while standing and weight-bearing and X-rays taken using the Yokokura method.

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The average age was 48.3±22.5 years, the average height was 162.5±11.1 cm, and the average weight was 57.8±12.4 kg.

How to measure flatfoot

Footprints were taken for all patients in the same position, and the longitudinal arch height ratio (the distance from the floor to the navicular bone divided by the foot length and multiplied by 100) was calculated [3,4] (Figure 1). and The correlation between this and the X-ray Yokokura method values c/Y, n/Y, and l/Y was examined[5] (Figure 2).

Statistical analysis was performed using Spearman's rank correlation coefficient (SCR) using JSTAT.

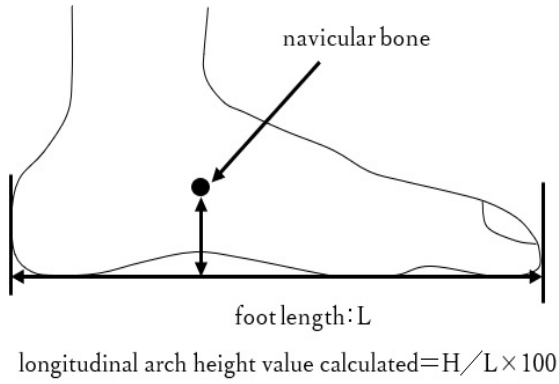

Figure 1: medial longitudinal arch height ratio

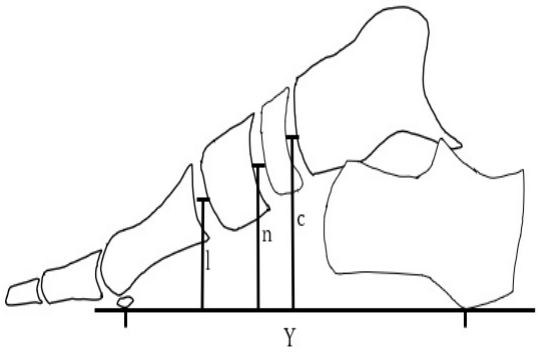

Figure 2: Yokokura's method [2)]

How to Measure Longitudinal Arch Height Ratio for Flatfoot Diagnosis

After determining the c/Y, n/Y, and l/Y values with the highest correlation to the longitudinal arch height ratio using the Yokokura method, the value with the highest correlation is applied to the formula to calculate the longitudinal arch height ratio at which flatfoot can be diagnosed.

The standard values for flatfoot are determined by subtracting 10% from the normal c/Y (men 34.8, women 33.6), n/Y (men 30.8, women 29.6), and l/Y (men 23.6, women 22.7) values using the Yokokura method. Values below these values are considered to be flatfoot.

The formula for calculating the standard longitudinal arch height ratio is (longitudinal arch height ratio: Yokokura method value = X: 10% below the normal Yokokura value).

The formula for men is longitudinal arch height ratio: lateral Kura value c/Y = X: 31.32. The formula for women is longitudinal arch height ratio: lateral Kura value c/Y = X: 30.24. This formula will give you the average and standard deviation index values.

All values at the positions with the highest correlation are entered into this formula to find the value of formula X, and the average value is calculated to calculate the reference value that allows for the diagnosis of flat foot based on the longitudinal arch height ratio value.

Reference Values for Flatfoot

For both men and women, c/Y, n/Y, and l/Y were correlated with longitudinal arch height at a significance level of 1%. High correlations were observed for c/Y (rs = 0.7654), n/Y (rs = 0.66871), and l/Y (rs = 0.635331). For men, high correlations were observed for c/Y (rs = 0.895536), n/Y (rs = 0.66871), and l/Y (rs = 0.688807). For women, high correlations were observed for c/Y (rs = 0.884615), n/Y (rs = 0.653846), and l/Y (rs = 0.659341).

For both men and women, c/Y and n/Y were correlated at a significance level of 1%, and l/Y was correlated at a significance level of 5%.

The flatfoot reference value for longitudinal arch height ratio was calculated using c/Y, which has the highest correlation for both men and women, and the average longitudinal arch height ratio for men was 15.7±0.7%, and for women it was 13.5±1.1 (Figure 3). Adding the standard deviation to this average value gave 16.4% for men and 14.6% for women, and subtracting the standard deviation gave 15% for men and 12.4% for women.

The flatfoot reference value based on longitudinal arch height ratio is at most 16.4% for men and 14.6% for women, and values below these for each gender were used as predictive values for suspected flatfoot.

Diagnosing Flatfoot Using Longitudinal Arch Height

A correlation was observed between longitudinal arch height and the Yokokura method, suggesting that longitudinal arch height is a reliable assessment method. This result is consistent with previous studies by Okubo et al. [3][4].

Based on the longitudinal arch height values and correlation graphs obtained for this case, we were able to predict the borderline for flatfoot based on longitudinal arch height.

We estimate that the borderline for flatfoot based on longitudinal arch height is 16.4% for men and 14.6% for women.

Standard values for splayed foot

Subject

The study included 36 patients (14 feet of 9 men and 48 feet of 27 women) with a total of 62 feet (4 right, 6 left, 25 bilateral) who had been diagnosed with splayfoot by a doctor using X-rays. The mean age

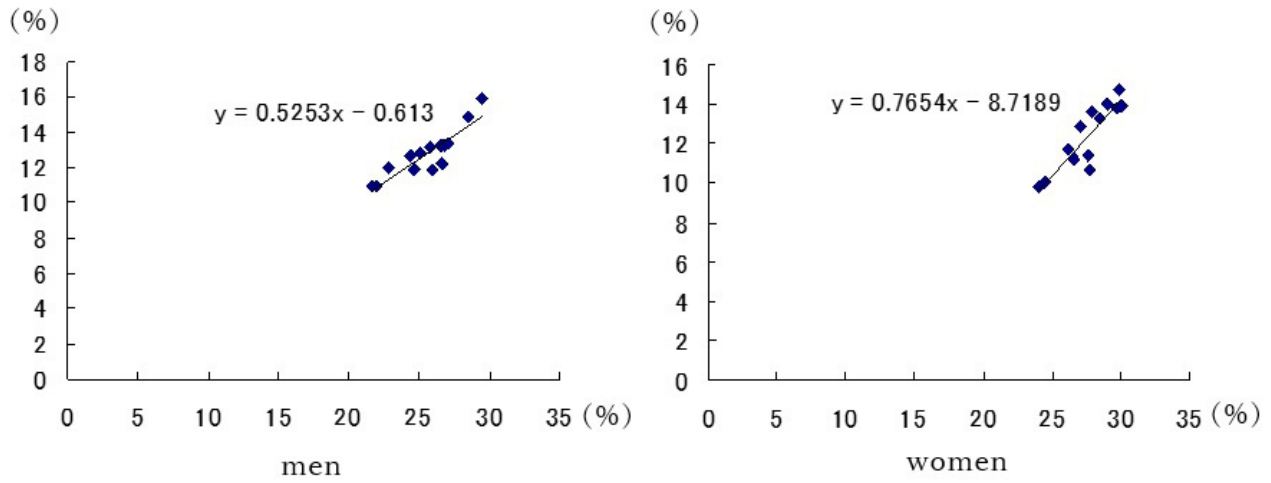

Figure 3: Correlation between C/Y obtained by Yokokura's method and the longitudinal arch ratio.

was 49.1±19.5 years, the mean height was 161.8±7.5cm, and the mean weight was 58.9±9.9kg.

Assessment of splayfoot

Splayfoot is measured using footprint analysis, where the foot width, which is the line connecting the first and fifth metatarsal heads, is divided by the actual foot length to determine the splay ratio [6] (Figure 4).

This splay ratio was compared with the first and fifth metatarsal angles (M1-M5 angle) on X-rays to determine correlation with X-rays (Figure 5). Statistical analysis was performed using Spearman's rank correlation coefficient (JSTAT).

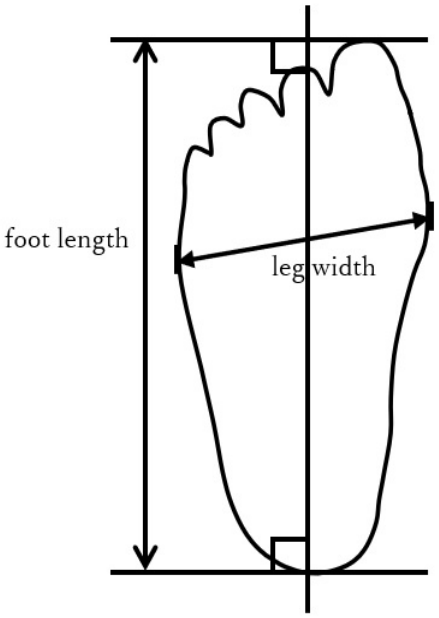

Figure 4: Spread Rate leg width/ foot length.

The diagnostic standard for splayfoot is an M1-M5 angle of 30 degrees or greater on an X-ray, so the formula for calculating the standard value for splayfoot is (splayfoot rate value: M1-M5 angle = X: M1-M5 angle).

All values are entered into this formula to find the value of X, the average is taken, and the standard value for splayfoot that makes it possible to diagnose splayfoot is calculated.

Calculate the splayfoot rate equivalent to an MI-M5 angle of 30 degrees.

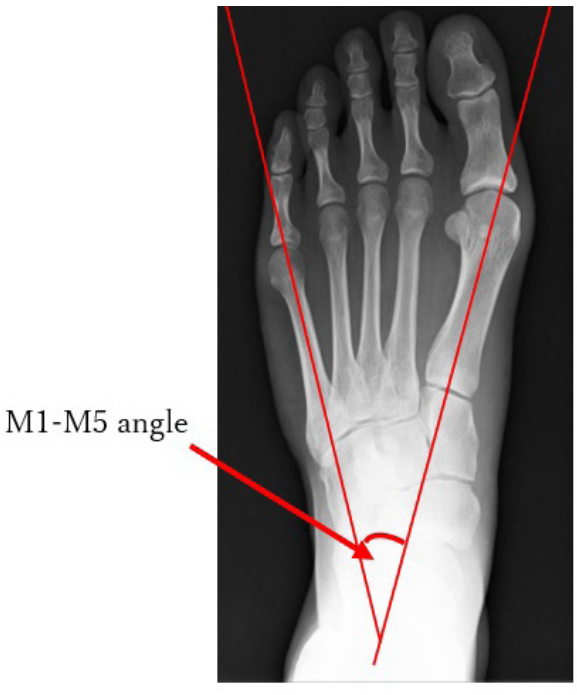

Figure 5: X-rays M1-M5 angle.

Reference Values for Splayfoot

For the M1-M5 angle on X-rays, the right splay rate was r = 0.64594 ($p < 0.0005$), the left splay rate was r = 0.466276 ($p < 0.00094$), and the combined splay rate was r = 0.535733 ($p < 0.0001$) (Figure 6). A high correlation was observed between the M1-M5 angle and splay rate at the 1% significance level.

The standard value for foot splay rate was an average splay rate of 39.4±5.0%. Because there was a large variation with a standard deviation of 5.0%, the regression equation Y=0.2669X+34.235 (M1-M5 angle) was used, and the standard value was further tightened by calculating it at -5°/25°.

The resulting Y value was 40.9075, meaning that a splay rate of 40.9% or higher was considered a predicted value.

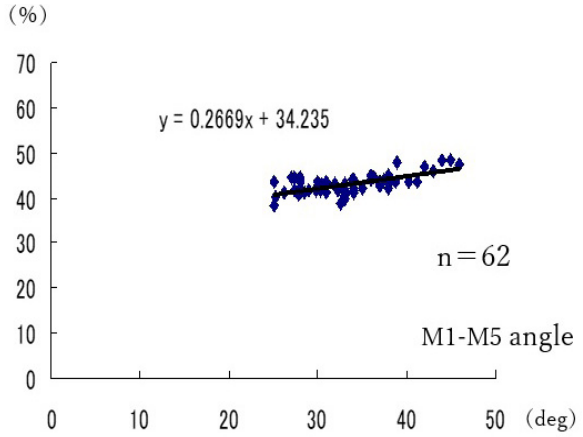

Figure 6: Correlativity of x-rays (M1-M5 angle) and a spread flatness.

Diagnosing splayfoot using the splay rate value

A correlation was observed between the splay rate and X-ray (M1-M5 angle), suggesting that splay rate is a reliable assessment method, similar to the results of a previous study by Nagayama et al. [6].

Since splayfoot is considered to be an M1-M5 angle of 30 or greater on X-ray, an M1-M5 angle of 30° was considered to be the borderline for splayfoot.

In the majority of cases in this study, the M1-M5 angle was 30° or greater, and the M1-M5 angle and splay rate for each case were calculated to determine a predictive value for a diagnosis of splayfoot.

In this study, the formula used was splay rate value: M1-M5 angle = X: M1-M5 angle, but there was a large variance of 5%, reducing reliability. Therefore, the index value was relaxed by calculating using the regression formula Y = 0.2669X + 34.235 (M1-M5 angle) and further calculating with a reference value of -5 degrees, or 25 degrees.

Therefore, based on the formula, a splay rate of 40.9% was considered a reliable indicator value for splayfoot.

Hallux valgus angle reference value

subject

A total of 32 cases and 56 foot were studied: 22 cases and 37 foot diagnosed by a doctor with hallux valgus and 10 cases and 19 foot diagnosed with flat foot.

The subjects were 23 cases and 40 foot of women and 9 cases and 16 foot of men, with an average age of 47.2±20 years, an average height of 159.8±10.3 cm, and an average weight of 56±12.1 kg.

Assessment of Hallux Valgus Angle

Hallux valgus is diagnosed when the hallux valgus angle on an X-ray is 20 degrees or greater. [7,8] In this study, we examined the correlation between the hallux valgus angle on a footprint and that on an X-ray, and calculated the predicted value of hallux valgus when using the hallux valgus angle on a footprint.

Here, we will use the hallux valgus angle from three footprint patterns (Figure 7) to see which pattern has the highest correlation and calculate the reference value for hallux valgus.

In the first pattern, we will look at the correlation between the angle (A) between the line connecting the first metatarsal head and the first proximal phalanx and the line connecting the first metatarsal head and the navicular tubercle as bone landmarks and the hallux valgus angle on X-rays.

In the second pattern, we will look at the correlation between the angle (B) between the line connecting the first metatarsal head and the first proximal phalanx and the line connecting the first metatarsal head and the center of the medial malleolus and the hallux valgus angle on X-rays.

In the third pattern, we will look at the correlation between the angle (C) between the line connecting the first metatarsal head and the first proximal phalanx and the line connecting the first metatarsal head and the posterior part of the medial malleolus and the hallux valgus angle on X-rays (Figure 7).

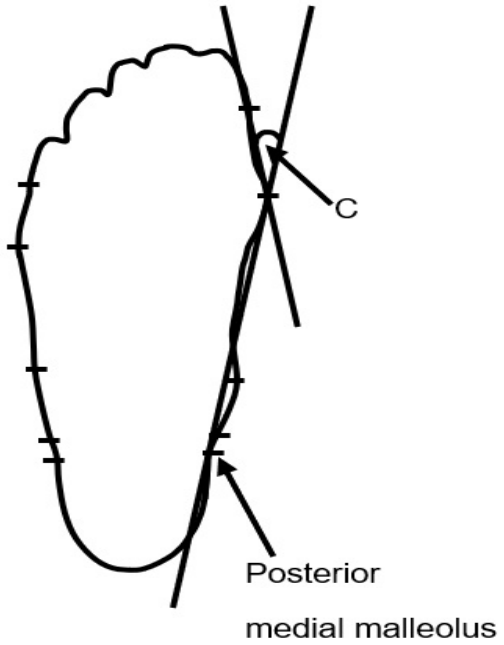

Figure 7: Comparison of hallux valgus angles in three patterns

The standard value for the hallux valgus angle on the footprint is determined by taking into account a hallux valgus angle of 20° or more on X-ray, which is the diagnostic standard for hallux valgus. The Y value is calculated from the formula: 20: Y = foot print angle: hallux valgus angle on X-ray, and the diagnostic standard value for hallux valgus is defined.

Diagnostic Criteria for Hallux Valgus

Comparing the hallux valgus angles, the correlation between X-ray was A r=0.932533, with B r=0.925644, with C r=0.942408, demonstrating high correlations between A, B, and C.

The angle between the line connecting the first metatarsal head and the first proximal phalanx and the line connecting the first metatarsal head and the posterior part of the medial malleolus in C showed the highest correlation (Figure 8).

C (Figure 8), which showed the highest correlation with hallux valgus on the footprint, was calculated for all cases using the formula: 20: Y = angle on footprint: hallux valgus angle on X-ray. The Y value was calculated for all cases using the formula: 20: Y = angle on footprint: hallux valgus angle on X-ray. As a result, a hallux valgus angle of 20° on X-ray was 16.25±3.16° on the footprint. Therefore, based on the hallux valgus angle of 16° or more on the footprint became the diagnostic criterion for hallux valgus.

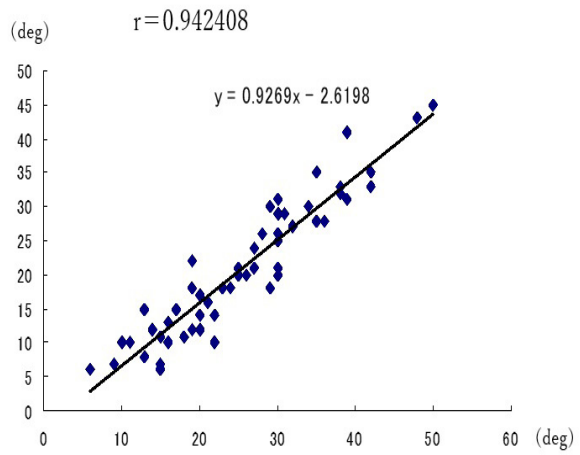

Figure 8: Hallux valgus angle C on X-ray and footprint.

Regarding hallux valgus diagnosis using the footprint hallux valgus angle

Uchida et al.'s first toe lateral angle reference line is a line connecting the first metatarsal head portion of the footprint's outer contour and the most distal tip of the heel, and the location of the most distal tip of the heel may differ for each case [9]. Therefore, we applied this first toe lateral angle to establish a reference line using bony landmarks and compared the hallux valgus angle between footprint and X-ray in three patterns. Correlation was observed for the hallux valgus angle in all three patterns, with the highest correlation observed in pattern C, which is based on a reference line passing through a point posterior to the medial malleolus and dropped onto the floor.

The navicular bone was used as bone landmark A because it was thought to be least affected by soft tissue and therefore to have the smallest error. Furthermore, the center and posterior part of the medial malleolus for B and C were set because we considered these to be close to the first toe lateral angle, which is based on a line passing through the most distal tip of the heel, as established by Uchida et al [9].

The diagnostic reference value was also clarified by applying the method with the highest correlation of the three patterns to a calculation formula. The diagnostic reference value for hallux valgus was calculated with 16° as the borderline, and anything more than 16 degrees was considered to be hallux valgus.

Discussion

Regarding the Measurement Position for Morphometric Measurements and Footprints

Measurements such as longitudinal arch height and footprints are affected by toe-out and toe-in positions. To increase reliability, the toe orientation was adjusted so that the medial edge of the foot faces the direction of forward movement.

Furthermore, because the ankle dorsiflexion angle during midstance is approximately 5°, the ankle was set at 5° of dorsiflexion [2]. It was believed that performing all assessments in the same position would result in more reliable results.

Clinical Significance

Since therapists cannot take X-rays, we need to evaluate the feet using other methods.

These reference values for flatfoot, splayfoot, and hallux valgus are estimated borderline values, which we believe will allow therapists to perform more reliable evaluations.

Since the reference values for flatfoot, splayfoot, and hallux valgus can be used to determine the presence or absence of foot disease, they can be used to provide advice to doctors in clinical settings.

They can also be used for medical checkups for athletes and other athletes.

Furthermore, they may be useful in research to select normal feet or to identify flatfoot, splayfoot, and hallux valgus. Therefore, we recommend them for clinical utility.

Summary

It is now possible to evaluate flatfeet, splayfoot, and hallux valgus using standard values without using X-rays.

For flatfoot, the borderline longitudinal arch height ratio is 16.4% in men and 14.6% in women; values below this value indicate suspected flatfoot.

For splayfoot, the borderline longitudinal arch height ratio is 40.9%, and values above this value indicate suspected splayfoot.

For hallux valgus, the borderline hallux valgus angle on the footprint is 16 degrees; values more than this value indicate suspected hallux valgus.

By clarifying these standard values, therapists can perform more reliable foot evaluations.

The reference values for flatfeet, splayfeet, and hallux valgus in this study can be used as a simple screening test that can be evaluated without taking an X-ray.

Screening tests make it possible to identify hidden foot disorders in advance, which can be useful for injury prevention.

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