A Quick and Reliable Procedure for Assessing Foot Alignment in Athletes

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Background: Quick procedures with proper psychometric properties that can capture the combined alignment of the foot-ankle complex in a position that may be more representative of the status of the lower limb during ground contact are essential for assessing a large group of athletes.

Methods: The assessed lower limb was positioned with the calcaneus surface facing upward in a way that all of the marks could be seen at the center of the camera display. After guaranteeing maintenance of the foot at 90° of dorsiflexion actively sustained by the athlete, the examiner took the picture of the foot-ankle alignment.

Results: Intraclass correlation coefficients ranging from 0.82 to 0.93 demonstrated excellent intratester and intertester reliability for the proposed measurements of forefoot, rearfoot, and shank-forefoot alignments. The intraclass correlation coefficient between the shank-forefoot measures and the sum of the rearfoot and forefoot measures was 0.98, suggesting that the shank-forefoot alignment measures can represent the combined rearfoot and forefoot alignments.

Conclusions: This study describes a reliable and practical measurement procedure for rearfoot, forefoot, and shank-forefoot alignments that can be applied to clinical and research situations as a screening procedure for risk factors for lower-limb injuries in athletes. (J Am Podiatr Med Assoc 103(5): 405-410, 2013)
In addition, combined misalignments of the forefoot and rearfoot seem to increase the susceptibility to the occurrence of injuries and degenerative processes. Somer and Vallen-tyne, for example, showed a relationship between the occurrence of medial tibial stress syndrome and the presence of combined forefoot and rearfoot varus alignments. However, this occurrence was not related to the presence of each segment misalignment by itself. Therefore, procedures that directly measure the combined alignment of the forefoot and rearfoot could be useful during screening assessments in the context of sports.

During preseason assessment, the used procedures should allow evaluation of the largest number of athletes in a short period. Ideally, alignment of the foot-ankle complex should be measured in a fast and reliable way. Thus, the use of photogrammetric approaches can help speed up this process. In these approaches, the athlete’s alignment can be quickly registered, and the images can be processed later to obtain the measurement values. Therefore, quantitative analysis can be done after the assessment, reducing the time spent with the athletes during the preseason assessment.

The procedures described in the literature for foot alignment measurements usually have poor reliability. For example, in many studies, during the assessment process, the subtalar joint is positioned in neutral and is maintained in an intermediary posture between inversion and eversion (0°). This positioning has been shown to have poor intertester reliability. In addition, despite the classic reasoning for measuring subtalar joint alignment in its neutral position, this position is not necessarily the position frequently assumed by the foot during the stance of closed-chain activities. This fact suggests the need for more functional foot positioning during alignment measurement. Holt and Hamill argued that the mechanics of the foot during ground contact depends more on the actual position of the foot at this moment (the functional state of the foot-ankle complex) than on the presumed neutral position. Because the ankle is actively positioned close to 0° of dorsiflexion/plantarflexion during most closed-chain activities, the measure of foot alignment in this position may better represent the influence of alignment on foot mechanics.

Quick procedures with proper psychometric properties that can capture the combined alignment of the foot-ankle complex in a position that may be more representative of the status of the lower limb during ground contact are essential for the assessment of a large group of athletes. The aims of the present study are 1) to develop standardized measurements of forefoot, rearfoot, and shank-forefoot alignments for quick and reliable use during athletes’ assessment processes and 2) to report the normative values of foot-ankle complex alignment for an athletic population.

Methods

This study was divided into two parts. In the first part, a reliability study was developed to assess the psychometric properties of the measure. In the second part, a larger number of individuals were assessed to obtain normative data of the values obtained with the proposed method. The measurement procedures were similar in both situations. Participants who had history of congenital deformity or surgery to either lower extremity in the previous 6 months were not included in any of the studies. This study was approved by the Ethics in Research Committee of Universidade Federal de Minas Gerais (Belo Horizonte, Brazil), and all of the participants provided written informed consent.

Reliability Study

Initially, 11 soccer and volleyball athletes (mean ± SD: age, 23.60 ± 7.13 years; height, 1.69 ± 0.09 m; and body mass, 62.20 ± 7.96 kg), 3 males and 8 females, were assessed for investigation of the intratester and intertester reliability of the measures. Two different examiners (L.D.M. and N.F.N.B.) performed the measurements in just one lower limb of each participant. Each examiner measured the same athletes twice, with an interval of 3 days between measurements. In the same evaluation session, the measures were performed with 20-minute intervals between them to avoid fatigue of the dorsiflexion muscles. Neither examiner could access the results obtained by the other. A third examiner (L.S.D.) cleaned all of the marks off the athlete’s skin during the interval between the evaluations to ensure that the examiners could not see the marks made by each other.

Normative Data Study

After the reliability investigation, 200 volleyball, basketball, and soccer athletes were evaluated to obtain normative data from an athletic sample. The participants were 75 females and 125 males (mean ± SD: age, 15.68 ± 3.86 years; height, 1.51 ± 0.62 m; and body mass, 64.53 ± 14.98 kg).
Foot Alignment Measurement Procedures

A digital photographic camera (Nikon D-SLR D5000; Nikon Inc, Melville, NY) was placed on a leveled support positioned at 90° in relation to the right lower extremity of a treatment table. To guarantee this positioning, an inclinometer and a goniometer were used. The viewing volume was defined, and marking tape was used to indicate on the table the correct placement of the athlete’s foot. The athlete was positioned prone with the feet off the table but with one of them between the tape marks. The medial malleolus was at the level of the table end to guarantee adequate visualization of the foot and shank in the pictures (Fig. 1).

The examiner used a caliper rule to mark, on the athlete’s skin, the central point between the tibial plateaus and between the superior boards of the malleoli. By means of palpation, the lateral and medial superior boards of the calcaneus were located and marked. Two other marks were made 1.5 cm below them. This procedure was used to avoid the limits of the calcaneus fat pad because it complicates palpation of the calcaneus borders and influences test reliability. After marking the calcaneus, the examiner fixed a hook and loop fastener (Velcro; Velcro USA Inc, Manchester, NH) band around the forefoot to attach a metallic rod that was placed in a way to follow the direction of the metatarsal heads. The assessed lower limb was positioned with the calcaneus surface facing upward in a way that all of the marks could be seen at the center of the camera display. One assistant maintained the lower limb in this position by holding the participant’s thigh during the assessment. The examiner used a flexible rule (80 cm) to connect the central marks between the tibial plateaus and malleoli and traced a straight line on the skin of the distal portion of the shank (Fig. 2).

The shank bisection procedure represents whole shank alignment and not just distal shank alignment. After the shank bisection was performed, the examiner used a goniometer to position the foot at 90° of dorsiflexion and asked the athletes to actively sustain this position. After guaranteeing the maintenance of this position, the examiner took the picture of the foot-ankle alignment (Fig. 3). The procedures for positioning and picture taking were performed three times.

The pictures were analyzed with Simi Motion (two-dimensional) software (Simi Reality Motion Systems GmbH, Unterschleissheim, Germany) by a third investigator (L.S.D.) who was not involved in the measurement procedure. In this analysis, the forefoot, rearfoot, and shank-forefoot alignment angles were determined. First, the calcaneus bisection was determined digitally using Simi Motion software. A midpoint between a line connecting the superior marks previously drawn and a midpoint between a line connecting the inferior marks, also previously drawn, were determined using the software. A digital line connecting these midpoints was determined and considered as the calcaneus bisection (Fig. 4). To obtain the angular values for the rearfoot, the angle between the shank bisection (Fig. 4) and the calcaneus bisection was measured. Forefoot alignment was quantified by the angle between the calcaneus bisection and a line following the direction of the metallic stem fixed on the metatarsal heads (Fig. 4).

A third measure was performed considering the angle between the shank bisection and a line following the direction of the metallic rod fixed on the metatarsal heads (Fig. 5). This angle represented shank-forefoot alignment.

In all of the measurements, varus alignments were reported as positive values and valgus alignments were reported as negative values.

Figure 1. Foot position for alignment assessment.

Figure 2. Positioning for the shank bisection procedure.
final result for each athlete was calculated as the mean value of the three measurement results in each variable evaluated (rearfoot, forefoot, and shank-forefoot alignment angles).

Results

The intratester and intertester reliability results for the forefoot, rearfoot, and shank-forefoot alignment measures are presented at Table 1. The ICC[3,3] between the shank-forefoot alignment measures and the sum of the rearfoot and forefoot alignment measures was 0.98, suggesting that the shank-forefoot alignment measures can represent the combined rearfoot and forefoot alignments. Normative values obtained with the rearfoot, forefoot, and shank-forefoot alignment measures of the 400 evaluated lower limbs are presented in Table 2.

Discussion

The aim of the present study was to assess the reliability of standardized measures of forefoot,
rearfoot, and shank-forefoot alignments. The results showed that the intratester and intertester reliabilities of these measures are good to excellent.\(^\text{15}\) The results also showed that the values obtained for shank-forefoot alignment are similar to values corresponding to the sum of the forefoot and rearfoot alignments. This finding corroborates the rationale that shank-forefoot alignment comprises the combined rearfoot and forefoot alignments. In addition, the present study provided normative values of these measures obtained from 200 athletes (400 lower limbs). The mean ± SD angles of forefoot and rearfoot alignments were 16.25° ± 8.97° and −1.83° ± 3.35°, respectively. Mean ± SD shank-forefoot alignment was 13.90° ± 9.88°. Therefore, the present study developed a reliable and practical measure, with a short period spent during the assessment process of foot-ankle complex alignment, which allows its use in preseason assessment of sports teams.

Some authors have reported rearfoot varus values of approximately 5°.\(^\text{1,6,20}\) However, the results of the present study showed a mean rearfoot alignment that is slightly valgus (−1.83°). This difference is possibly due to procedures related to the positioning of the ankle during the evaluation. In the present study, the athlete was requested to actively sustain the ankle at 90°, regardless of the actual position of the subtalar joint. Therefore, the measurement taken during active positioning of the ankle at 90° demonstrated a slight valgus to neutral rearfoot alignment instead of the expected rearfoot varus positioning obtained with classic measures.

Mean forefoot alignment angle values reported in the literature are approximately 8°.\(^\text{1,20,21}\) However, the present study found a mean angle of 16.25° for this measure. The active maintenance of the ankle at 90° requires isometric contraction of the dorsiflexion muscles because the resting position of this joint corresponds to more plantarflexed positions.\(^\text{22}\) The tibialis anterior muscle generates an inversion torque on the forefoot that may contribute to the greater forefoot varus values found.\(^\text{4}\) This actively maintained position allows the identification of soft-tissue alterations that can affect forefoot mobility and increase forefoot varus. Impairments such as inversion hypermobility of the forefoot and dorsiflexion hypermobility of the first rays may affect this measurement and produce increased values of forefoot varus. Therefore, this procedure allows capturing the effect of not only the forefoot bony alignment but also the mobility of the forefoot, including the first and second rays. Considering these features, this measure may represent foot functional mechanics better than measures performed with the subtalar joint in the neutral position.\(^\text{4}\)

This is the first study to investigate shank-forefoot alignment. The results showed a mean ± SD value of 13.9° ± 9.88° for shank-forefoot alignment. This mean varus value is related to the sum of the slight valgus rearfoot and the high varus forefoot values found for the sample of 200 athletes. The procedures permit a fast and practical assessment that can be performed in approximately 3 minutes for each athlete. As mentioned previously herein, the shank-forefoot alignment and forefoot measures are also sensitive to the first-ray and forefoot hypermobilities. The use of shank-forefoot alignment measures during screening assessments makes the measurement process easier and allows the detection of possible foot-ankle misalignments that may increase the risk of injuries and help the health team plan a preventive program.

Previous studies investigating the reliability of foot-ankle complex alignment measures did not show good intertester reliability values.\(^\text{16,17}\) The present study obtained good to excellent intertester ICC[3,3] values (0.82 and 0.91 for the rearfoot and forefoot, respectively). The nonuse of subtalar joint neutral positioning and the standardized procedures proposed could have contributed to these results. The obtained reliability values for the assessment of foot-ankle complex alignment indicate that the method proposed might be used for clinical and research purposes.

The major limitation for the proposed procedure is the need for adequate training before performing the measures. The examiner must practice to
properly determine the calcaneus bisection, which proved to be the most difficult procedure. However, the examiner can choose to measure only shank-forefoot alignment during the preseason assessment. Shank-forefoot alignment can be used as an initial screening method for later detailed examination of foot-ankle complex alignment. Rearfoot and forefoot alignments can be measured after the preseason assessment using the methods evaluated in the present study or by means of classic subtalar joint neutral positioning.

This study describes a reliable and practical measurement procedure for rearfoot, forefoot, and shank-forefoot alignments that can be applied to clinical and research situations as a screening procedure for risk factors for lower-limb injuries in athletes. The use of shank-forefoot alignment measurement allows comprehensive and fast assessment of foot-ankle complex alignment.

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References