# A weight bearing method for determining forefoot posting for orthotic fabrication

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*ABSTRACT Orthotic prescription for forefoot posting is commonly based upon measures of the forefoot performed on a non-weightbearing foot. However, the relationship of measures of the unloaded foot to determine orthotic prescription for compensatory forefoot function during gait is still in question. Another approach to determine orthotic prescription is to measure the height of forefoot posting necessary to prevent excessive pronation of the subtalar joint during weightbearing. Therefore, the purpose of this study was to determine the intrarater, interrater and day-to-day reliability of forefoot measures during an active, weightbearing movement. Thirty-two volunteers, 18 females (mean age 38.9 ± 15.3 yr) and 18 males (mean age 44.8 ± 20.6 yr) participated in the study. Four examiners performed repeated forefoot measures on both feet using the weightbearing technique during two test sessions separated by a week. Intrarater and interrater reliability (ICC (3,1)) ranged from 0.90 to 0.95 and 0.87 to 0.94, respectively. Day-to-day reliability (ICC (1,1)) ranged from 0.84 to 0.88 for all measures. We conclude that the weightbearing method used in this study to determine forefoot posting is reliable. The acceptable reliability of this method justifies the need for future investigations of the validity and the clinical efficacy of this technique for orthotic prescription.*

**Key words:** forefoot, orthotic prescription, reliability, weightbearing

## INTRODUCTION

During the stance phase of gait, neutral alignment of the foot is proposed to occur when the heads of the metatarsals lie perpendicular to the vertical calcaneus. As weight is transferred from the rearfoot to the forefoot, the neutral alignment between the forefoot and the rearfoot allows the first metatarsal to bear weight without the need for excessive pronation of the subtalar joint (Tiberio, 1988). According to Root, et al. (1977), a foot with an osseous forefoot varus deformity is subject to injury due to the excessive talar pronation as weight is transferred from the rearfoot to the forefoot.

Root et al. (1977) proposed a non-weightbearing method for measuring forefoot varus and valgus conditions. The test position recommended for measurement of the relationship of the forefoot to the rearfoot was with the subject lying prone on a plinth. These measures are then used for orthotic prescription. An assumption was made that non-weightbearing measures of forefoot varus and/or valgus conditions were highly correlated to dynamic foot function during gait.

Although results from studies by Garbalosa et al. (1994) and Johanson et al. (1994) have supported the reliability of the non-weightbearing measurement method, the validity of the correlation among non-weightbearing, static forefoot measures, dynamic foot function and orthotic prescription remain in question. Brown et al. (1995) have expressed a need for further evaluation and clarification of foot biomechanical measures that may be used for orthotic prescription.

The present study follows a different measurement approach in which compensation required to prevent talar pronation was measured during weightbearing in a controlled squat that placed weight on the forefoot. The weightbearing technique under investigation in this study was developed by Brian Rothbart, in an attempt to provide a more functional measure of the forefoot for orthotic prescription (Rothbart, 1994). The weightbearing method involved observing the movement of the head of the talus while the subject performed a partial squat from a standing position. The movement of the tibia over the fixed foot was intended to imitate the impact of weightbearing on

FIGURE 1: Example of a partial squat as the examiner palpates the head of the talus.

the foot in the gait phase from foot flat to the beginning of toe off (Figure 1).

The decision to use a bilateral relaxed stance in this system is supported by recent data from McPoil and Cornwall (1996). They indicated that the position of the rearfoot in the bilateral relaxed stance also occurred during the gait cycle, approximating the angle found during the first 10 degrees of gait (McPoil and Cornwall, 1996). In addition, there was no benefit to control for subtalar joint neutral since this position correlated poorly with rearfoot motion during gait. A more logical measurement position was the bilateral relaxed stance used in this study, and was reported to correlate very highly with foot positions during the gait cycle (McPoil and Cornwall, 1996).

In the present study, measures were made of the height of support under the first metatarsal head which is required to prevent talar pronation during the squat. Thus, the present system involved the measurement of the actual vertical height of forefoot posting needed to stabilize the talus when weight was transferred from the rearfoot to the forefoot. This paradigm was conceived as a potentially more effective method to use for the prescription of orthotics than the non-weightbearing approach proposed by Root and Orien (1977). The purpose of this study was to determine the intrarater, interrater and day-to-day reliability of compensatory forefoot measures during an active, weightbearing movement.

## METHODS

### *Subjects*

Thirty-two subjects, 16 males and 16 females, were recruited from a large University student and staff population and from physical therapy clinics in a large metropolitan area. Subjects were excluded from the study if any of the following conditions were present:

- prior use of foot orthotics,
- a dermatomal distribution of pain in either lower extremity,
- foot pain,
- lower extremity paralysis,
- hallux valgus
- hammer toes.

Each subject gave written consent prior to testing. Physical characteristics of the subjects are presented in Table 1.

TABLE 1: Description of subjects (mean ±SD, N=32)

| *Gender* | *Age (years)* | *Height (cm)* | *Weight (kg)* |
|---|---|---|---|
| Female | 28.9 ± 15.3 | 150.5 ± 19.0 | 67.6 ± 3.5 |
| Male | 44.8 ± 20.6 | 160.7 ± 32.9 | 69.8 ± 5.2 |

*Examiners*

The examiners were four physical therapists with an average of 8.5 years of clinical practice experience, who had not had prior exposure to the present system of forefoot measurement. One therapist had nine years of experience in foot evaluation and orthotic prescription; the other three had none. Two training sessions lasting 45 minutes each were conducted by a physical therapist experienced in the use of the present technique for the examiners to learn and become consistent in the use of the measurement system and techniques. During the week between training sessions, each examiner was asked to practice forefoot measurements using the present technique on pilot subjects. Subjects measured during training sessions or during practice in the clinics did not participate in the study.

*Data collection protocol*

Each of the four examiners measured each subject on two different days for a total of eight sessions per subject. The measures on each subject were separated by a week. Height and weight were measured initially. Forefoot measures were made at each session. The purpose of the second test session for each subject by each therapist was to determine day-to-day reliability of the method.

*Test procedures*

The forefoot was measured bilaterally using a wedge called a biovector. The biovector was constructed of inch nickleplast material stacked to make a wedge 1 inch high x 1 inch wide x 1 inch long. The biovector was calibrated in 1mm vertical increments on one end only that could be seen by an independent investigator (Figure 2). A pair of biovectors (one for each foot) was used by each examiner so the calibration marks could be oriented away from the examiner but could be seen by an independent investigator who recorded the data. Each biovector was calibrated using a micrometer, prior to data collection.

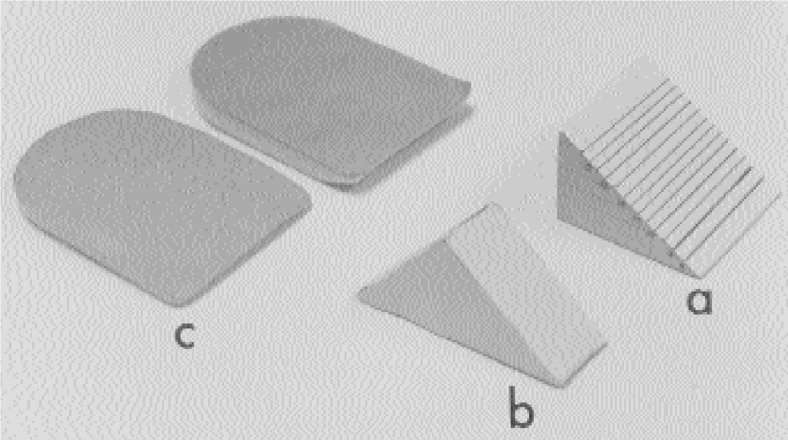


FIGURE 2: Examples of (a) heel wedges, (b) a talar block and (c) a biovector wedge.

At the beginning of each test session, the subject stood without shoes on an 80cm high cabinet-grade plywood platform. The subject faced away from the examiner with both heels placed comfortably apart and 15.24 cm from the rear of the platform. To approximate weightbearing stress on the feet during gait, subjects were asked to perform a partial squat. The partial squat was demonstrated to the subject by the examiner. The subject was instructed to try several foot positions while performing the partial squat, until a foot position was determined that resulted in the most comfortable position. If the subject reported a feeling of tightness' in the triceps surae muscles during the partial squat, felt heel wedges in increments of 6mm were inserted under the calcaneus until the subject no longer reported any 'tight' feeling in the triceps surae muscles. The final position chosen was recorded by outlining the subject's feet on paper to standardize the position for successive tests.

After the foot placement was established, while the subject remained standing, a biovector was slid under the first metatarsal by the examiner and the subject was asked if a touch or pressure sensation was felt (Figure 3). The goal was to initially place the biovector far enough under the first metatarsal for the subject to feel a touch but not a deep pressure sensation under the first metatarsal in the resting position (full standing). The subject was also asked whether the sensation of pressure under the first metatarsal caused by standing on the biovector was equal at the front and back of the biovector. The purpose of sensing equal pressure was to determine if the biovector was parallel to the first metatarsal.

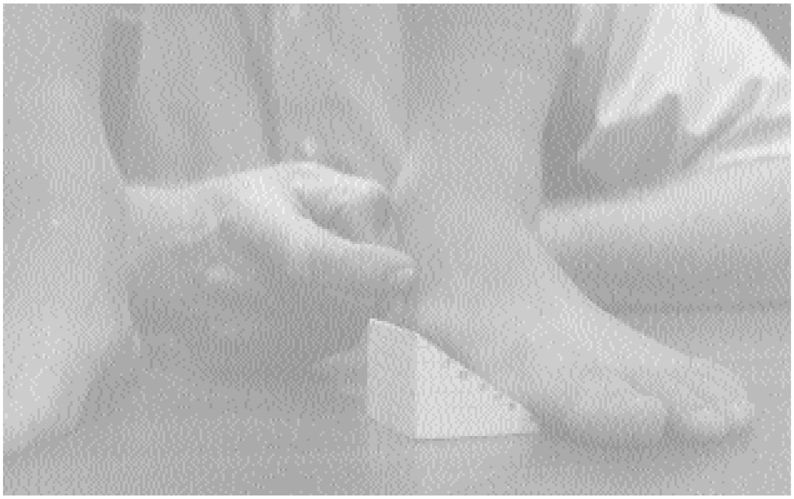

FIGURE 3: Positioning of a biovector wedge under the first metatarsal.

Following the placement of the biovector, the subject was asked to perform a partial squat while the examiner palpated the medial aspect of the head of the talus to determine the amount of talar adduction during weightbearing. If the head of the talus was determined to adduct greater than approximately one millimeter, the biovector was then slid under the head of the first metatarsal to provide one millimeter of additional vertical support. The process continued until the head of the talus adducted approximately less than one millimeter during the partial squat. At this point, the position of the talus was considered sufficiently supported and pronation was prevented. The vertical height measured on the biovector was used as the prescription for forefoot and midfoot posting for an orthotic. During the measurement procedure there was usually a visually observable reduction in talar drop with each additional millimeter increment of vertical support. If the addition of one millimeter of vertical support was not observed to reduce talar drop during the partial squat, a hypermobile first ray was assumed. To compensate for the assumed hypermobile first ray, a second wedge was inserted under the talus as a talar block (Figure 4).

The talar block was also constructed of stacks of inch nickleplast material that measured 1 inch high x 1 inch wide x 1 inch long. A pilot study supported the assumption that the talar block would provide sufficient support to the hypermobile first ray thus allowing reliable measurements. Determination of the necessity and placement of a heel wedge and/or a talar block was determined independently by each examiner during each trial. If use of a talar block was deemed necessary, the examiner placed the talar block under the head of the talus while the subject was standing, and restarted the measurements. When the examiner had determined that the talus no longer continued to drop during the squat procedure, the examiner used his/her thumbnail to mark the line on the biovector where the head of the first metatarsal rested. The biovector was then removed and shown to an independent investigator who recorded the measure in order to reduce examiner bias. The examiner performing the test was not allowed to see the value on the biovector. Three biovector measures were made by each examiner on each foot during test sessions on each of the two days. The complete measurement procedure for both feet lasted approximately five minutes. Subjects rested in a sitting position for 10 minutes before being measured by a second pair of examiners.

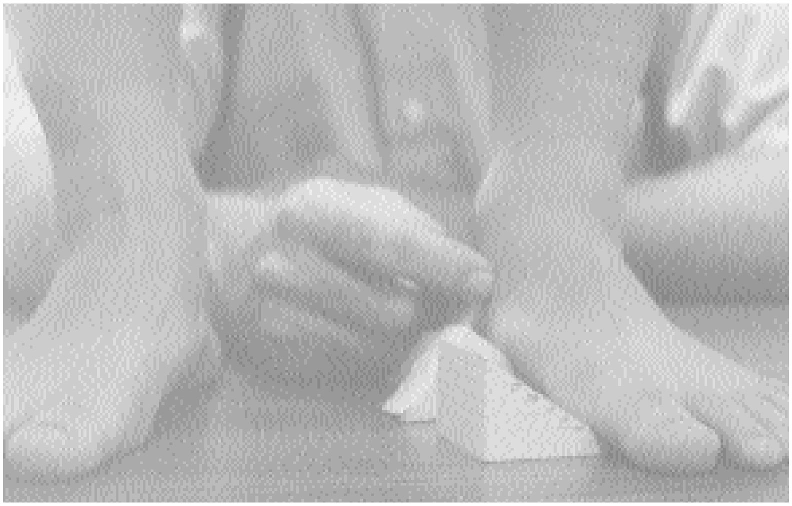

FIGURE 4: Positioning of a biovector wedge and talar block.

*Statistical analysis*

Intrarater and interrater reliability for forefoot displacement measures were determined by calculating an ICC (3,1) (Shrout and Fleiss, 1979). Intrarater reliability was determined by comparing each examiner's three measures per foot per day. Interrater reliability was determined by comparing the mean of three trials for each examiner per day. Day-to-day reliability was determined by calculating an ICC (1,1) (Shrout and Fleiss, 1979) that compared the group means for each foot between the two days, and an independent t-test was used to determine any differences.

Reliability of the measures among the trials and raters and between days was considered to be high if the ICC value was between 0.90 and 0.99, good between 0.80 and 0.89, fair between 0.70 and 0.79, and poor below 0.69. The standard error of measurement was calculated to determine the difference between the absolute and predicted forefoot measures in mm (SEM = SD 1-ICC) (Thomas and Nelson, 1990). An alpha level of ps0.05 was used for all tests of significance.

## RESULTS

The means and standard deviations for all measures on each foot per day are summarized in Table 2. Reliability coefficients for intrarater and interrater reliability measures and standard errors for the forefoot measures are summarized in Table 3. Reliability coefficients and t-ratios for day-to-day reliability measures for the forefoot measures are summarized in Table 4.

## DISCUSSION

The purpose of this study was to determine the intrarater, interrater and day-to-day reliability of forefoot measures made during an active, weight-bearing movement. The results indicated good to high intrarater, interrater and day-to-day reliability of the measures.

To date, we have found no other studies that have evaluated the reliability of this or any other forefoot measurement technique utilizing forefoot measures made during a weightbearing movement. Garbalosa et al. (1994) evaluated a commonly used non-weightbearing forefoot measurement technique and reported a high (ICC = 91.9) interrater reliability that is similar to the range of interrater reliability (ICC = 0.87 - 0.94) reported in this study. However, the efficacy of using prescrip-

TABLE 2: Mean (SD) for forefoot measures (N=32)

| *Forefoot Measure (mm)* | *Examiner 1* | *Examiner 2* | *Examiner 3* | *Examiner 4* | *Combined* |
|---|---|---|---|---|---|
| Right Foot | | | | | |
| Day 1 | 13.8 ± 2.6 | 12.8 ± 3.3 | 11.8 ± 3.8 | 12.4 ± 3.3 | 12.7 ± 3.3 |
| Day 2 | 13.3 ± 2.8 | 12.1 ± 2.7 | 11.5 ± 3.8 | 14.2 ± 4.2 | 12.8 ± 3.6 |
| Left Foot | | | | | |
| Day 1 | 13.6 ± 3.4 | 12.9 ± 3.7 | 12.1 ± 3.5 | 13.5 ± 3.4 | 13.0 ± 3.5 |
| Day 2 | 13.5 ± 3.2 | 14.1 ± 6.8 | 10.9 ± 3.3 | 14.6 ± 4.8 | 13.3 ± 4.9 |

TABLE 3: Reliability coefficients and standard errors of measurement for forefoot measures (N=32)

| *Forefoot Measure (mm)* | *Intrarater* | | *Interrater* | |
|---|---|---|---|---|
| | *ICC** | *SEM* | *ICC* | *SEM* |
| Right Foot | | | | |
| Day 1 | 0.90 | 1.0 | 0.87 | 1.2 |
| Day 2 | 0.94 | 0.88 | 0.92 | 1.0 |
| Left Foot | | | | |
| Day 1 | 0.95 | 0.78 | 0.94 | 0.86 |
| Day 2 | 0.92 | 1.4 | 0.90 | 1.5 |

*ICC (3,1) = intraclass correlation coefficient
*SEM = standard error of measurement*

TABLE 4: Reliability coefficients and t-ratios for day-to-day reliability measures of forefoot measures (N=32)

| | *Day-to-day* | |
|---|---|---|
| *Forefoot Measure (mm)* | *ICC** | *t-ratio* |
| Right Foot | 0.84 | 0.176 |
| Left Foot | 0.88 | 0.513 |

*ICC (1,1) = intraclass correlation coefficient

tions determined by either static (non-weightbearing) or dynamic (weightbearing) measurements to control dynamic foot function has yet to be determined.

*Limitations*

Although three of the four examiners participating in this study did not have any prior experience measuring forefoot conditions, each examiner did have 6-11 years of experience as a practicing physical therapist. Therefore, generalization of the reliability of this measurement technique to therapists with little practice experience should be cautioned. A second limitation of the generalizability of this technique is that the measurements, although taken during an active partial-squatting position, were made while both feet were on the floor which does not directly correspond to a normal gait pattern. Although the ICC values reported in this study were good, they might be improved if a consistent squat pattern could be determined for each subject.

*Clinical implications*

The use of the biovector as a clinical tool to measure for forefoot orthotic prescription during weightbearing provides reliable information for the clinician. The present method proposed and tested in this study may provide superior data to the clinician for the determination of orthotic prescription compared to a static measurement technique (Garbalosa et al., 1994). Further study comparing the present forefoot measurement technique to existing techniques are warranted to examine the ease of use and validity of the measures. If orthotic prescriptions should be found to vary between the two methods, biomechanical studies should be conducted to determine the relative effectiveness of either method for controlling gait dynamics affected by forefoot varus. Establishment of reliability of the present technique warrants further study of the validity of measures using this and other forefoot measurement techniques for predicting optimal orthotic prescriptions.

## CONCLUSIONS

The present study demonstrates the high reliability of a weightbearing technique used to measure forefoot varus. Although clinicians experienced in general orthopedic evaluation and treatment were used to collect the data, three of the four clinicians lacked experience measuring forefoot varus and required a relatively short training period in order to learn and become competent with the present technique. The accuracy of the results from this study may not be generalizable to physical therapists with little to no clinical experience. Clinicians experienced with other static measurement techniques may find this alternative technique useful in determining orthotic prescription.

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