Comparison of Three Methods Used to Obtain a Neutral Plaster Foot Impression

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The purpose of our study was to compare the forefoot-to-hindfoot angles obtained from three methods used to obtain a neutral plaster impression of the foot. The three methods were 1) supine nonweight-bearing (S), 2) prone nonweight-bearing (P), and 3) sitting semiweight-bearing (SW). We obtained foot casts from both feet of 11 female subjects for each of the three methods and used a manual goniometer to measure the forefoot-to-hindfoot angle for each pair of casts. The F *ratios were significant for the variables left-right foot* ($p < .0001$) *and impression method* ($p < .001$) *using a within-subject two-factor analysis of variance. The impression methods S and P were found to be significantly different from SW, but not significantly different from each other, using a Tukey's* post hoc *comparison. The results indicate that the same forefoot-to-hindfoot alignment can be obtained using either the S or P method but not with the SW method. [McPoil TG, Schuit D, Knecht HG: Comparison of three methods used to obtain a neutral plaster foot impression. Phys Ther 69:448–452, 1989]*

Key Words: *Foot deformities; Lower extremity, ankle and foot; Orthotics/splints/casts, lower extremity; Tests and measurements, general.*

The fabrication of a foot orthosis requires both an accurate evaluation of foot structure and the precise duplication of the foot morphology through the use of a neutral plaster impression.[1] The purpose of the neutral plaster foot impression is to replicate the patient's forefoot-to-hindfoot alignment that would occur at the mid-stance phase of the walking cycle.[2] At the instance of mid-stance, the subtalar joint should be in a neutral position, that is, neither pronated nor supinated.[3] Also during mid-stance, the midtarsal joint becomes fully locked, causing the plane of the metatarsal heads to be placed in a position that is perpendicular to the bisector of the calcaneus.[4] Thus, the normal forefoot-to-hindfoot alignment at the point of mid-stance should be 90 degrees.

To duplicate the mid-stance position of the foot, the neutral plaster impression should be performed with the subtalar joint in neutral and the midtarsal joint fully locked.[5] Brown and Smith state that the principle cause of incorrect positioning of the foot when taking the neutral plaster impression is the failure to fully lock the midtarsal joint.[1]

Forefoot deformities, whether acquired or developmental, can alter the normal forefoot-to-hindfoot alignment and contribute to abnormal movement patterns in the foot.[2,6] Two developmental deformities that can occur in the forefoot are a varus or valgus.[4] Forefoot varus has been described as a cause of pes planus

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and hallux abducto valgus, whereas a forefoot valgus is often present in patients diagnosed with pes cavus.[6-8] The treatment program for a patient with a forefoot deformity can include a foot orthosis, which would require a neutral plaster foot impression.

The three most common methods used to obtain a neutral plaster foot impression are the supine nonweight-bearing (S) method, the prone nonweight-bearing (P) method, and the sitting semiweight-bearing (SW) method. Valmassey has discussed the advantages and disadvantages of all three impression methods.[5] He suggests that the forefoot-to-hindfoot alignment obtained by the SW method will be different in comparison with alignments obtained with the S or P impression methods. He has hypothesized that this difference is caused by the inability to fully lock the midtarsal joint when the foot is in a semiweight-bearing position.

Although differences in these three neutral impression methods have been suggested, we could find no previous research that compared the forefoot-to-hindfoot alignment angles obtained with different neutral plaster impression techniques. Thus, we designed this study to compare the forefoot-to-hindfoot alignment angles obtained by these three impression methods. Our null hypothesis was that no significant difference would exist among the forefoot-to-hindfoot alignment angles obtained using the S, P, or SW impression methods. The two independent variables for our study were the subjects' two feet (factor A) and the three impression methods (factor B).

Method

Subjects

Eleven subjects, between the ages of 18 and 30 years ($\bar{X} = 23.4, s = 2.1$), were selected from a volunteer pool of 62 women. Based on a series of oral questions, only subjects who had no history of injury to the foot, ankle, or lower leg 12 months prior to data collection were selected. The study was approved by an institutional review board, and all subjects signed an informed consent statement prior to participation.

Procedure

Using the procedure to determine the forefoot-to-hindfoot alignment described by McPoil and Brocato,[9] we performed an evaluation on each subject to identify whether a forefoot deformity existed. One subject had a forefoot varus, eight had a forefoot valgus, and two had no forefoot deformity. We chose to consider each subject's foot individually because all subjects, except the two subjects with no forefoot deformity and one subject with a valgus deformity, demonstrated a difference in the degree of forefoot deformity bilaterally. Additionally, we have reported previously that in a sample of 58 women, 69% exhibited the same type of forefoot-and-rear foot deformity bilaterally, indicating the importance of considering each foot individually for both assessment and plaster impression procedures.[10]

Neutral plaster foot impressions, using each of the three impression methods, were taken bilaterally for each subject. We used a random numbers table to assign the order of subject testing for the foot and the three impression methods to be studied. One experimenter (TGM) performed all casting procedures.

The S impression method was performed with the subject placed in the long sitting position. Using the same procedure as described by Root et al,[3] we applied four layers of plaster-of-paris splints to form a cast slipper of each foot. After application of the plaster splints, we then palpated the neutral position of the subtalar joint with the thumb and index finger of one hand as described by Burns et al.[11] The midtarsal joint was fully locked by a force applied through the thumb of the other hand, placed in the plantar sulcus of the fourth and fifth digits, to dorsiflex and abduct the forefoot (Fig. 1). We removed the neutral plaster foot impression when

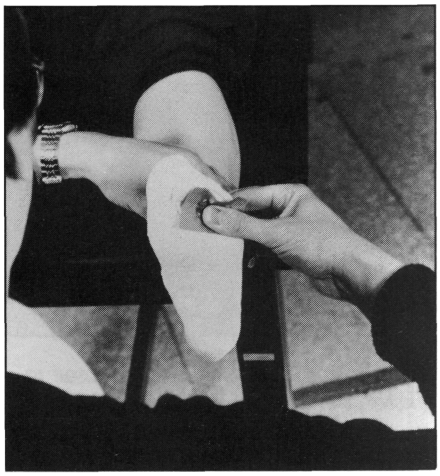

Fig. 1. *Thumb of evaluator's hand being used to lock midtarsal joint during application of supine nonweight-bearing neutral plaster impression method.*

Fig. 2. *Palpation of subtalar joint neutral position and thumb position for locking midtarsal joint during application of prone nonweight-bearing plaster impression method.*

dry and repeated the procedure for the other foot.

For the P impression technique, we placed each subject on her stomach and then used the same method described by McPoil and Brocato[9] to

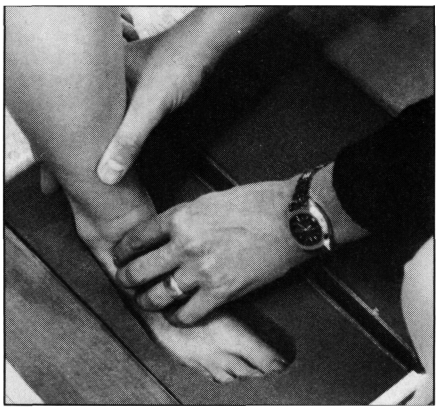

Fig. 3. *Palpation technique used to ensure subtalar joint neutral position during application of sitting semiweight-bearing plaster impression method.*

obtain the neutral foot impression. Four plaster-of-paris splints were placed around each foot to form a cast slipper. The subtalar joint neutral position was palpated with one hand, and a force was applied through the thumb of the other hand, placed over the plantar aspect of the fourth and fifth metatarsal heads, to dorsiflex and abduct the forefoot (Fig. 2). When the plaster dried, we removed the cast slipper from the subject's foot. The procedure was repeated for the other foot.

We asked each subject to assume the sitting position for the SW technique. The instructions provided by the manufacturer of the foam casting box* used to take the foot impressions were followed. These instructions included having the subject sit with the trunk maintained in the erect position, the thigh placed parallel to the floor, and the lower leg perpendicular to the floor. The talocrural joint was neither dorsiflexed nor plantar-flexed. The subject's foot was placed over the foam casting box, and the neutral position of the subtalar joint palpated. After the subject was instructed to completely relax, the entire foot was pushed into the foam material. The neutral position of the subtalar joint was palpated continuously during the procedure

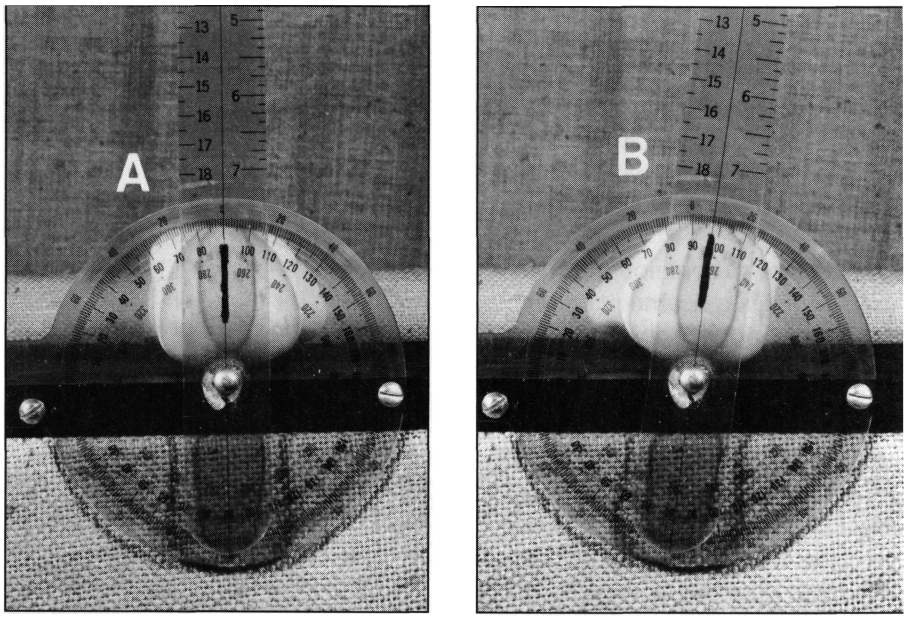

Fig. 4. *Goniometric measurement of forefoot-to-hindfoot alignment for (A) a neutral impression model and (B) a forefoot varus impression model.*

(Fig. 3). We then repeated the procedure for the other foot.

We periodically palpated the extrinsic muscles of the foot during the application of all three procedures to prevent distortion of the neutral foot impression molds while the plaster of paris was drying. Upon completion of the three impression methods for each subject's feet, we filled each of the three pairs of neutral molds with plaster of paris to form a plaster model of the foot. When the plaster of paris was dry, we removed the models from either the slipper casts or foam casting box.

One tester (TGM) took two measurements for each of the subject's six plaster models, using a standard manual goniometer fixed to a wooden baseboard (Fig. 4). A random numbers table was used to assign the order in which the measurements were taken.

Data Analysis

To determine the reliability of the evaluator who measured the forefoot-to-hindfoot angles, intraclass correlation coefficients (ICC[2]) were performed using the two measurements for each of the three plaster models of each subject's foot.[12] We used a two-factor analysis of variance (ANOVA) for repeated measures to determine whether the overall F ratio for factor A (feet), factor B (impression methods), or the interaction were significant.[13] We used a Tukey's *post hoc* comparison to determine differences among the treatment means. The alpha level selected for our study was .05.

Results

Intraclass correlation coefficients for the S, P, and SW methods on both the left and right feet are listed in Table 1. Means and standard deviations are listed in Table 2. The results of the ANOVA were significant for factor A ($p < .0001$) and factor B ($p < .001$) (Tab. 3).

The Tukey's *post hoc* comparison on the main effects for factor A was significant ($p < .05$) between the left foot ($\overline{X} = 5.45$) and the right foot ($\overline{X} = 8.74$). Tukey's *post hoc* comparison on factor B resulted in significant differences ($p < .05$) between the following treatment means: 1) S and SW and 2) P and SW. No significant difference was found between the P and S treatment means.

*Smithers Bio-Medical Systems, PO Box 118, Kent, OH 44240.

Discussion

Our first concern in analyzing the results of our data was the evaluator's reliability in repeatedly measuring the forefoot-to-hindfoot angles for each of the three impression methods. Based on the ICCs reported, we believe that the measurement technique used by the evaluator was effective.

The results of our study, although conducted on a small group of subjects, showed that the same forefoot-to-hindfoot alignment angle can be obtained using either the S or the P technique, but not with the SW technique. Based on these findings, we rejected our null hypothesis because significant differences were found among the three neutral impression methods tested in this investigation. Although the intent of our study was not to determine which of the three methods evaluated was optimal, our findings suggest that the physical therapist can expect differences in the forefoot-to-hindfoot alignment when using a semiweight-bearing versus nonweight-bearing neutral impression method.

Our results would support Valmassey's opinion regarding the variation in forefoot-to-hindfoot alignment when the SW method is used for obtaining a neutral foot impression in comparison with the P and S methods.[5] The SW method requires less training and is easier to perform than either the P or the S method. Although palpation of the subtalar joint can be accomplished in the SW method, it could be hypothesized that the midtarsal joint cannot be fully locked as the foot is forced into the foam box. Further research would be required to determine whether the variation in forefoot-to-hindfoot alignment noted with the SW method is caused by the inability of the midtarsal joint to be fully locked because of the semiweight-bearing position or by other factors such as the density of foam selected to obtain the foot impression.

We also found a significant difference in the forefoot-to-hindfoot alignment between the left and right feet for each subject. Nine subjects (81%) had the same type of forefoot deformity bilaterally, based on the evaluation of the forefoot-to-hindfoot alignment conducted prior to performing the foot impressions. Eight of the nine subjects, however, had a difference in the degree of forefoot deformity bilaterally, with a mean variation in deformity of 3.3 degrees between the left and right feet. We believe this difference in the degree of forefoot deformity for these eight subjects bilaterally accounts for the significant findings noted between the left and right feet for the subjects in this study. These results further emphasize the need for the physical therapist to consider each foot of the patient separately for both evaluation and plaster impression method.

A disadvantage of our investigation was that the 11 subjects selected were asymptomatic for at least 12 months prior to the start of data collection. We would speculate, however, that our subjects' forefoot deformities, used to evaluate the three neutral impression methods in this study, are no different than the forefoot deformities found in patients with foot disorders requiring physical therapy.

Table 1. *Intraclass Correlation Coefficients for Three Neutral Impression Methods by Left and Right Foot*

	Method[a]		
Foot	S	P	SW
Left	.99	.99	.93
Right	.95	.95	.87

[a]S = supine nonweight-bearing; P = prone nonweight-bearing; SW = sitting semiweight-bearing.

Table 2. *Forefoot-to-Hindfoot Angle Descriptive Statistics for Three Neutral Impression Methods (in Degrees)*

	Method[a]		
	S	P	SW
$\bar{X}$	9.39	8.05	3.86
s	1.58	1.36	0.96

[a]S = supine nonweight-bearing; P = prone nonweight-bearing; SW = sitting semiweight-bearing.

Summary

Based on the results of our study, the same forefoot-to-hindfoot alignment can be obtained using either the S or

Table 3. *Results of Analysis of Variance for Neutral Impression Methods*

Source	*df*	SS	MS	*F*
Foot (A)	1	178.37	178.37	20.11[a]
Subject (S)	10	421.07	42.10	
A × S	10	88.67	8.87	
Method (B)	2	365.10	182.55	11.35[b]
B × S	20	321.57	16.08	
A × B	2	3.24	1.62	
A × B × S	20	203.60	10.18	
TOTAL	65	1581.62		

[a]$p < .0001$.

[b]$p < .001$.

the P method, but not with the SW method. A difference in the degree of forefoot deformity could also be expected between the left and right feet.

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