A New Device for Improving Foot Marker Alignment

Roy Wervey[1] and Michael Schwartz[1,2,3]
[1]Gillette Children's Specialty Healthcare
[2]University of Minnesota, Department of Orthopaedic Surgery
[3]University of Minnesota, Department of Biomedical Engineering

Introduction: Most clinical gait laboratories employ a simplified, one-segment, single-vector foot model. Misalignment of the markers used to define the foot vector leads to inaccuracies and increased variability in the measurement of dorsi-plantar flexion, foot progression and ankle rotation angles. Errors and variability in these angles is a significant problem since these metrics are frequently used in diagnosis and treatment planning. In an internal quality assurance study conducted in 2001, we observed a higher than expected degrees of intra- and inter-observer variability between staff physical therapists in foot progression and dorsi-plantar flexion angles [1]. As a result of these findings, we designed and constructed a device to aid in proper alignment of foot markers.

Statement of Clinical Significance: The use of a novel foot alignment device (FAD) results in accurate and repeatable foot vector definition.

Methodology: The motion analysis laboratory at Gillette Children's Specialty Healthcare employs a standard, single-segment, one-dimensional foot model (Vicon Clinical Manager 1.37, Oxford Metrics, Oxford UK). Two markers are used to define the foot. Forefoot and heel markers are placed so that they are parallel to the long axis of the foot. The long axis is defined by a transverse plane (plantar surface) projection of a vector from the ankle center to a point on the dorsum between the second third metatarsophalangeal joints. During the static exam, an attempt is made to place the forefoot and heel markers parallel to the plantar surface of the foot. Static plantarflexion (SPF) is then defined as the angle between the ankle center-to-forefoot vector and the heel-to-forefoot vector, projected into the sagittal plane of the foot. Static Foot Rotation (SFR) is the angle between these same vectors projected into transverse plane (plantar surface).

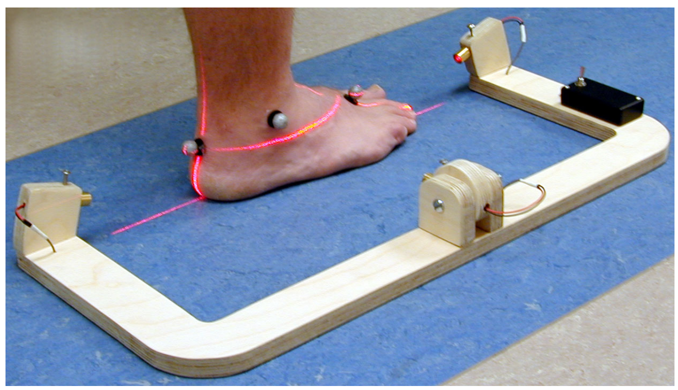

Figure 1. The FAD. The anterior laser intersects the forefoot marker and the ankle center. The horizontal laser bisects the forefoot marker. The posterior and horizontal lasers form a target for the heel marker.

The foot alignment device (FAD) consists of a U-shaped frame and three laser line-generators, mounted on the frame as shown in Figure 1. The laser line generators project thin red lines onto the dorsum, heel and medial or lateral surface. To use device the forefoot marker is placed on the foot. The mid-malleolar point is marked to approximate the ankle center. Next, the U-frame is manually rotated until the anterior laser line intersects both the forefoot marker and the ankle center. The horizontal laser line is then adjusted until it bisects the forefoot marker. The horizontal and posterior lasers cross on the heel, forming a target for the heel marker.

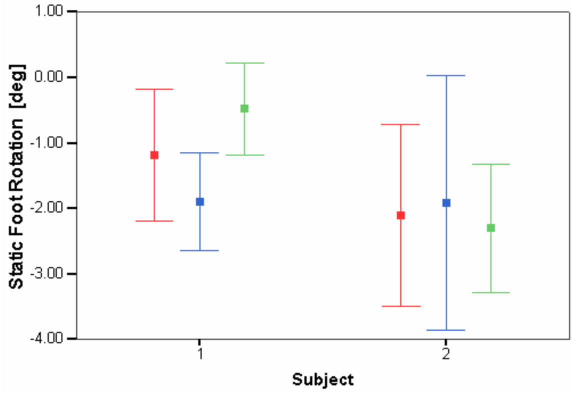

Figure 1. The SFR (mean ± 1SD) for the two subjects shows a high level of accuracy (mean) and repeatability (SD). No differences were found between physical therapists and technicians.

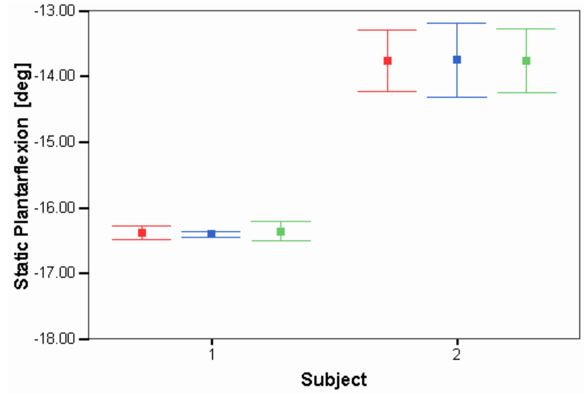

Figure 2. The SPF (mean ±1 SD) for the subjects shows a high level of repeatability. No differences were found between physical therapists and technicians. Nominal values of the SPF are subject specific, accounting for the difference in means.

To test the repeatability of the FAD we recruited 3 physical therapists and 3 lab technicians to place the heel marker on 2 subjects. Prior to the placement of the heel marker, the approximated ankle center was marked and markers were placed on the malleoli and the forefoot. Three seconds of marker position data was collected using a 12 camera optoelectronic motion capture system (Vicon 512, Oxford Metrics, Oxford UK). The SPF and SFR angles for each subject and each observer were then calculated. The nominal value of the SFR is 0.0 so the SFR data was pooled between subjects. The SPF depends on the subject's anatomy; therefore the two subjects were analyzed separately.

Results: The overall transverse plane accuracy and repeatability of the FAD were 2.1° and 1.4° respectively (SFR) [Figure 2]. In the sagittal plane repeatability was found to be 0.10° and 0.47° for subjects 1 and 2 respectively (SPF) [Figure 3]. Sagittal plane accuracy cannot be assessed since the nominal value of the SPF is unknown. In terms of accuracy and repeatability, there were no differences between therapists (PT) and technicians (TC).

Discussion: The FAD gave accurate and repeatable measures for the SFR and SPF angles. The device and methodology are designed to be objective. This was borne out by the fact that therapists and technicians alike were able to obtain equally accurate and repeatable results. The experimental design used in this study was intended to isolate the placement of the heel marker as the single source of variation. In practice, additional variability will be introduced by the placement of the malleolar marker and by the identification of the ankle center. These factors are beyond the control of the FAD. It appears that a slight transverse plane mal-alignment existed in the prototype FAD despite the precise woodworking and craftsmanship of our laboratory engineer. This is suggested by the non-zero mean SFR. A production unit FAD would be constructed using precision machining, thereby eliminating this offset. These initial results indicate that accurate and repeatable foot definition can be practically and easily achieved using the FAD.

References:

1. Trost JP, Schwartz MH and Wervey RW, Gait Posture, 16(suppl. 1):8-9, 2002.