THE RELIABILITY OF SUBTALAR JOINT NEUTRAL AND RANGE OF MOTION MEASUREMENTS

Stephan J. LaPointe, D.P.M.

The measurements of subtalar joint neutral and range of motion are performed routinely by podiatrists in clinical practice. These measurements are part of a thorough biomechanical exam. The subtalar joint neutral is the datum from which the range of motion is assessed. Prescriptions for orthoses are based on these biomechanical measurements. The subtalar joint is maintained in the neutral position while molding negative casts for orthoses. The values for range of motion and neutral position are communicated to other podiatrists and health care professionals and the manufacturer of orthoses. They play an important role in the course of treatment and communicating with others. It is important that these measurements are reliable and accurate for them to be meaningful. The following is a review of the literature concerning the definition of subtalar joint neutral and the ability to properly measure it.

DEFINITION

What is subtalar joint neutral? The American Academy of Orthopaedic Surgeons defines it as the position when the bisection of the lower leg is parallel to the bisection of the heel.[1] The problem is that any deformity such as tibial varum or rearfoot valgus makes this definition inapplicable. For instance, a patient with fully compensated rearfoot varus may be at the end range of eversion when the calcaneus is aligned with the tibia. This definition cannot be applied to every case.

Root observed that there was a point during inversion and eversion of the calcaneus at which the motion was purely in the frontal plane.[2,3] This position was defined as subtalar joint neutral. Motion from this position is free of transverse and sagittal plane motion. At the neutral position, the subtalar joint is neither supinated nor pronated. Root also noted that full supination from neutral required two-thirds of the range of motion. This led to a formula for calculating subtalar joint neutral. Namely the total range of motion multiplied by two-thirds and subtracted from leg neutral is subtalar joint neutral. He imposed two other conditions on subtalar joint neutral. The neutral position was that position immediately following heel strike and again at 50% of stance. The third criteria was that it was the only position at which the plantar plane of the forefoot would be parallel to the rearfoot. Although this may describe the ideal or normal foot, imposing all three conditions on the typical foot is not possible.

Bailey used stress tomograms to measure the amount of inversion and eversion at the subtalar joint.[4] The motion was measured between the tibia and the calcaneus including motion that occurred at the ankle joint. The neutral position was determined by palpating the talonavicular joint and placing it in a position of maximum congruency. The average eversion was 36.2% of the total range of motion. This correlated fairly well with the observations made by Root. However, few subjects measured close to the one-third criteria. The range and standard deviation of the measurements proved that this definition was not practical when assessing a particular case.

In stance, Root described the neutral calcaneal stance position with three criteria: 1) congruity of the medial and lateral edges of the talus to the calcaneus at the subtalar joint; 2) the concavity on the lateral surface of the foot is parallel to the concavity on the lateral surface of the distal leg; 3) the lateral surface of the foot describes a straight line in the care of the calcaneocuboid joint. The first criterion is the only one found in the literature that directly evaluates congruity at the subtalar joint. Any pronation or supination would make the talus or calcaneus prominent and require an adjustment for placing the foot in neutral. However, as in the open kinetic chain definition of neutral, the average foot does not fulfill all three parts of this definition.

Elveru argued that subtalar joint neutral should have "construct validity" or measure what it is supposed to measure.[5] Elveru stated that the palpation method described by Wernick and Langer[6] has construct validity. He referenced studies by Hlavac[7] and Inman[8] that reported the talonavicular and subtalar joints were both in neutral when maximally congruent. Elveru inferred that since both joints are maximally congruent at neutral, that when the talonavicular joint is maximally congruent (i.e. in neutral) so is the subtalar joint. Elveru described a technique based on those by Wernick and Langer,[6] James,[9] McPoil and Brocato[10] and Gray[11] as follows. In the prone position, the patient's foot is pronated and dorsiflexed to a soft end feel. The head of the talus either cannot be palpated or is equally palpated along its medial and lateral borders at its articulation with the navicular. This position is subtalar joint neutral.

Root's first criteria for neutral calcaneal stance position, is the only one which directly places the subtalar joint in neutral by forcing it to be in maximum congruency. The weight-bearing nature of this definition is also more likely to better reflect the position in which the foot functions. Most of the literature, which evaluates the reliability of subtalar joint neutral measurements, uses Elveru's or a similar definition involving talonavicular congruency.[12-18]

MEASUREMENTS

Assuming that a definition is established, somehow the neutral position and range of motion must be measured. The measurements must be reliable and accurate. All the clinical techniques for measuring subtalar joint neutral require some type of a goniometer. Reliability of goneiometric measurements are questionable and the topic of several investigations. Two studies have addressed the reliability of goniometer measurements on the lower extremity.

Ekstrand addressed the intrarater reliability of ankle dorsiflexion measurements as well as five other lower extremity measurements.[19] An orthopedic surgeon and physical therapist performed all measurements. The results were reported as coefficient of variance. This is the standard deviation as a percentage of the quantity being measured. They performed two series of measurements. The first series consisted of following a written description of a measurement protocol. The coefficient of variation for ankle dorsiflexion with the knee straight was 10.5% and with the knee bent 9.6%. The knowledge gained during the first series was used to optimize the measurement technique. The equipment was modified and bony landmarks were marked to standardize the placement of the goniometers. In the second series the coefficient of variation improved to 2.5% and 2.6% for the knee straight and bent respectively. Experience gained and modifications made to the technique resulted in roughly a four-fold increase in reliability.

Boone studied the intratester and intertester reliability of lower and upper extremity goniometric measurements.[20] The lower extremity motions included foot inversion. Four testers measured three upper and three lower extremity motions that were repeated three times at four different sessions. The testers were physical therapists with twenty years of experience. The three measurements were averaged to produce one measurement per session. Repeated measures analysis of variance and Neuman-Keuhls multiple comparison tests were performed on the data to determine significant differences. Significant differences were seen among the testers for each of the joint motions. The intraclass correlation coefficient (ICC) was used to quantify reliability of the measurements. Perfect reliability would be reflected by a value of 1.0. The minimally acceptable value for the ICC is 0.70. The intratester reliability for foot inversion was 0.795, and the intertester reliability was 0.687. There was a decreased reliability for lower extremity measurements when compared to the upper extremity. For instance the intratester and intertester ICC's for shoulder outward rotation were both above 0.96. Moderate to low reliability was noted with lower extremity measurements. Boone recommended that only one tester make all measurements for a single patient due to poor interrater reliability.

Several studies have been performed to assess the reliability of open kinetic chain measurements at the subtalar joint. Diamond evaluated the intratester and intertester reliability of measuring subtalar joint neutral, inversion and eversion and other measurements in the diabetic population.[15] Twenty patients were tested three times on one occasion by the initial examiner. A second examiner also tested all patients. The testers had extensive training with twenty sessions over an eighteen-month period. The palpation of talonavicular joint congruency was used to measure subtalar joint neutral. The statistics performed were the intraclass correlation coefficient (ICC)[2,1] and the standard error of measurement (SEM). The SEM units are the same as those measured. In this case, it is degrees. The SEM follows the ICC in parentheses for the following measurements. Subtalar joint neutral intrarater reliability was 0.96 (1) for the left lower extremity and 0.74 (0) for the right. The interrater reliability was 0.79 (2) and 0.62 (3) for the left and right respectively for neutral. Intrarater reliability for inversion and eversion range of motion varied from 0.92 (1) to 0.96 (2). Interrater reliability for the same measurements was between 0.78 (2) and 0.89 (4). Diamond argued that the ICC's were artificially low due to the small variation in the population. Since the SEM values were small, it supported the use of these measurements. He concluded that extensive training could improve the reliability in subtalar joint neutral and range of motion measurements.

Pierrynowski also used the talonavicular joint palpation technique to measure subtalar joint neutral.[18] He compared the reliability of eight chiropodists with eight untrained physical therapy students. The statistics reported included the repeated measures analysis of variance. The mean and standard deviation were used to estimate the percentage of measurements that would fall within different error ranges. Forty-one point three percent of the measurements for chiropodists were within plus or minus one degree. Only 25% of the student measurements were within this range. The same measure for plus or minus two degrees was 72.3% and 47.6% for chiropodists and students respectively. Pierrynowski concluded that, although training and feedback in measurement errors could improve the reliability of subtalar joint neutral measurements, there was significant room for improvement.

Elveru conducted repeated measures of the subtalar joint neutral, inversion and eversion range of motion and ankle dorsiflexion and plantarflexion to assess their reliability.[21] Fourteen physical therapists with an average of six-and-a-half years experience conducted the measurements. Intratester reliability, expressed as ICC's, was 0.77 for subtalar joint neutral, 0.62 for inversion and 0.59 for eversion. The intertester estimates were 0.25 for neutral position, 0.15 for inversion and 0.12 in eversion. Additionally the reliability of the testers to determine whether the neutral position was in varus, valgus or neutral relative to the leg was only 0.35. Elveru stated that subtalar joint neutral measurements were not clinically useful because of poor reliability, especially between different testers.

Several investigators, including Picciano, compared open kinetic chain and closed kinetic chain measurements of subtalar joint neutral.[14] All these studies used palpation of the talonavicular joint for placing the subtalar joint in the neutral position. ICC and SEM in parentheses were 0.06 (1.81) and 0.27 (2.43) for two physical therapy students. The intertester reliability was 0.00 (2.51). Picciano measured the closed kinetic chain neutral position using a goniometer. The intratester ICC was 0.14 (2.46) and 0.18 (2.40) for the two student examiners. The intertester ICC was 0.15 (2.43). Neither open kinetic chain nor closed kinetic chain measurements were reliable. Picciano concluded that clinicians should perform their own trials to determine their measurement reliability and that experience may improve reliability.

A study by Smith-Oricchio addressed measurement error of subtalar joint neutral in open and closed kinetic chain and by calculation of the mathematical model.[17] The palpation technique was used to perform measurements prone, and in bilateral and unilateral stance. Three physical therapists tested twenty patients. The prone position had an ICC of 0.60. The mathematical model was abandoned because of extremely low inversion and eversion measurement reliability. Bilateral stance resulted in an ICC of 0.91. Unilateral stance reliability was 0.75. Smith-Orrichio recommended performing weight-bearing measurements of subtalar joint neutral for improved reliability.

Sell assessed the reliability of closed kinetic chain measurements using an inclinometer or gravity goniometer.[22] Two testers and sixty limbs of thirty volunteers were tested. One student and one physical therapist performed the tests. Subtalar joint neutral was measured during bilateral stance. The measurement was made with a gravity goniometer against the bisection of the calcaneus. The angle of the bisection to the weight-bearing surface was measured at neutral and at rest. The ICC with SEM in parentheses were reported. Intratester ICC at rest was 0.85 (1.1) and 0.85 (1.2) in neutral. Intertester reliability was poor for resting stance 0.68 (1.3) and fair for neutral stance 0.79 (1.8). This study showed that the simpler closed kinetic chain technique is more reliable than open kinetic chain measurement of subtalar neutral.

Many of the studies concluded that subtalar joint neutral measurements were unreliable, and all suggest these measurements could be more reliable.[14,17,18,21,22] Several sources of error may exist in these measurements. The first source of error is in the ability to properly bisect the calcaneus. Some of the studies did relate that the bisection was erased between measurements, but many inferred that they did not. Not one study described the technique used for bisection of the calcaneus or heel. Even if properly performed, the calcaneal bisection is a source of error. Once the heel is manipulated, there is motion between the skin and the calcaneus that results in measurement error. Elveru did not bisect the calcaneus because they determined it was a major source of error with range of motion measurements. Root attempted to compensate for this error by scribing a different bisection at each end range of motion.

Using the lower leg as a reference point in measuring subtalar joint neutral and range of motion introduces additional sources of error. Bisection of the lower leg may not be reliable. Movement at the heel may displace the bisection resulting in further error. Since the measurement is made between the leg and heel, the ankle introduces additional error. Several open kinetic chain studies have recognized this and have attempted to compensate by dorsiflexing the ankle to eliminate motion in the frontal plane.[5,14,17,21] Sell eliminates this source of error by using a gravity goniometer up against the bisection of the heel.[22]

Experience and feedback on measurement error proved to improve the reliability of the subtalar joint neutral and range of motion data.[15,18,19] The ideal technique would be universally accepted and could be performed by most health care providers with minimum training. Improving the protocol by simplifying it, eliminating sources of error and standardizing the approach could compensate for the lack of examiner experience.

SUMMARY

An experimental protocol has been developed to investigate 1) the reliability of bisecting the calcaneus; 2) the effect of motion on the calcaneal bisection and 3) the effect of weight bearing on the calcaneal bisection. Hopefully this will provide information on one source of error. A more reliable approach to measuring subtalar joint neutral is needed. Understanding the sources of error may lead to more reliable techniques for measuring subtalar joint neutral and range of motion.

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