Goniometric Reliability in a Clinical Setting

Subtalar and Ankle Joint Measurements

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Measurements of the subtalar joint neutral (STJN) position and passive range of motion (PROM) of the ankle joint and the subtalar joint (STJ) are often part of a physical therapy evaluation. These measurements may be used in treatment planning, such as in the prescription of specialized shoes or orthoses. Therefore, reliability of these measurements, as they are obtained clinically, must be determined. The purpose of this study was to examine the reliability of measurements of the STJN position and of ankle and STJ PROM. To determine reliability, repeated measurements of the STJN position and of STJ PROM were taken on the involved feet of 43 patients with neurologic orthopedic disorders (including both feet of 7 patients), and measurements of ankle PROM (dorsiflexion and plantar flexion) were taken on 42 of these patients (including both feet of 7 patients). Intraclass correlation coefficients (ICCs) for intratester reliability ranged from .74 to .90 for ankle and STJ measurements. The ICCs for intertester reliability were .25 for measuring the STJN position, .32 for STJ inversion, and .17 for STJ eversion. The ICCs for intertester reliability were .50 for ankle dorsiflexion and .72 for ankle plantar flexion. Goniometric measurements of the STJN position and of PROM of the ankle and STJ appear to be moderately reliable if taken by the same therapist over a short period of time. With the exception of ankle plantar flexion, these measurements cannot be considered to be reliable between therapists.

Key Words: *Ankle joint; Lower extremity, ankle and foot; Tests and measurements, range of motion.*

In clinical practice, the universal goniometer is frequently used to measure the subtalar joint neutral (STJN) position and the passive range of motion (PROM) of the ankle and subtalar joint (STJ). These measurements may be taken on a patient serially over time and possibly by more than one therapist. Therefore, both the intratester and intertester reliability of these measurements must be known if they are to be used in clinical decision making. The purpose of this study was to examine the reliability of measurements of the STJN position and of PROM of the ankle and the STJ.

Little information is available concerning the reliability of the measurements of the foot and ankle. For example, Baldwin and Graebner[1] examined the reliability between two testers in measuring STJN position with a goniometer and a "K-square."[2] When the data these authors reported are used to calculate an intraclass correlation coefficient (ICC, equation 1,1),[3] no significant agreement exists between testers.

Viitasalo and Martii measured STJ range of motion in 15 young adults.[4] The STJ was first placed in neutral. The ankle was then dorsiflexed maximally, and the posterior leg and heel were placed in either maximal inversion or maximal eversion. While the foot was in each position, tracings were made on a transparent sheet. Measurements were then made from the transparencies. Although the authors reported a correlation coefficient of .84, whether this value represents an index of intratester or intertester reliability is unclear.

Alexander et al measured motion of the ankle joint and the STJ joint with a specially made device that consisted of a footplate mounted on a ball joint.[5] The authors presented data for active ROM and PROM measurements collected from 10 male and female subjects whose ages ranged from the second to the eighth decade of life. A coefficient of variation (CV) was used to determine reliability. The CV is the sample standard deviation expressed as a percentage of the sample mean. The CV reflects the variation in measurements taken on a sample of subjects from a population. The size of the CV depends on the standard deviation, which reflects both true variation (because of individual differences between subjects) and measurement error. Unfortunately, because Alexander et al measured multiple subjects, it is not possible to separate measurement error from true intersubject variability.

Pandya et al recently evaluated the reliability of goniometric measurements on patients with Duchenne muscular

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dystrophy.[6] Their ICC values for ankle dorsiflexion were .90 (intratester) and .73 (intertester). However, the type of ICC that was used was not reported. Other researchers have reported better intratester reliability than intertester reliability.[7,8] Therefore, measurements of ankle dorsiflexion appear to be reliable for this well-defined patient group.

The intratester and intertester reliability of determining the position of STJN and PROM of the ankle and the STJ has not been described for other patient types. A study describing the clinical reliability of these measurements would give therapists an indication of their usefulness. Therefore, the research questions for this study were

1. What is the degree of intratester and intertester reliability for measurements obtained with a goniometer for the position of STJN?
2. What is the degree of intratester and intertester reliability for measurements obtained with a goniometer for ankle and STJ PROM?

METHOD

Subjects

Subjects were 43 patients, aged 12 to 81 years ($\bar{X}$ = 35.9 years), with neurological or orthopedic disorders referred to the Department of Physical Therapy, Medical College of Virginia Hospital, Richmond, Va. Both feet of seven of the patients with orthopedic disorders were measured so that reliability was examined for measurements of 50 feet. The criterion for admission was that the position of STJN and PROM of the ankle and the STJ would be an appropriate part of the physical therapy assessment. All subjects signed a consent form before admission to the study. Additional subject data were collected so that if necessary these factors could be used in a posteriori analyses to determine whether they had an effect on reliability. Table 1 gives a description of the characteristics of the patient sample.

Testers

Goniometric measurements were made by 14 volunteer physical therapists employed by the Medical College of Virginia Hospital. The therapists had a mean of 6.5 ± 3.0 years of experience and had graduated from 11 different physical therapy schools. Before the study, the therapists had limited or no experience in measuring the STJN position or STJ PROM with a goniometer; that is, they measured STJN or STJ PROM no more than once every two weeks. More experienced therapists were excluded from the study to determine whether physical therapists who were not necessarily experts could follow a written protocol and perform reliable measurements. We believed that experts might be biased for or against the techniques used in this study. They would also have knowledge and experience not shared by most therapists, and the reliability of their measurements would have little generalizability to most clinicians. We felt that the reliability of the therapists we selected would be representative of the reliability that could be expected in other physical therapy departments.

Before measuring a patient, participating therapists were given an instruction form explaining the techniques for measuring STJN position and STJ PROM.[9] Therapists were allowed to practice taking the required STJ measurements until they stated that they felt confident in their ability. The primary author (R.A.E.), although present at all practice sessions, gave no guidance in the actual measurement techniques. All therapists required one or two practice sessions with a mean total time of 31.3 ± 0.4 minutes (range = 15-60 minutes).

Instrumentation

Nine small plastic goniometers* were used. The accuracy of the goniometers was determined before the study by using each goniometer to measure six randomly chosen, computer-generated angles between 0 and 180 degrees drawn by a graphics plotter.† All goniometers had 5-in‡ moveable arms, with the goniometer's scale marked in 1-degree increments. To prevent the testers from being biased by their previous readings, tape covered the scales on the side facing the tester. To record the measurements, the recorder read the reverse side of the goniometer.

Procedure

The procedure was a modification of methods originally described by Rothstein et al[7] and Riddle et al.[8] The measurement techniques for the STJ were those described by Elveru et al (see accompanying article by Elveru and colleagues in this issue). Therapists were randomly paired for each patient measured. Each therapist was assigned a number, and these numbers were used to generate random number lists. Each therapist was given a different list. Each time a therapist (called the referring therapist) identified a patient for the study, he progressed down the random list and was paired with the next available therapist on the list.

The referring therapist positioned the patient in prone and then palpated the STJN position. With the blinded side of the goniometer toward the therapist, the arms of the goniometer were aligned with the longitudinal midline of the posterior calcaneus and a line drawn on the leg. The goniometer was handed to the recorder who read and recorded the number of degrees from the nonblinded side. The therapist again put the patient's foot into the STJN position and then maximally inverted the heel. The leg-calcaneal angle was again measured with the blinded goniometer. The goniometer was then handed to the recorder for reading and recording from the nonblinded side. This same procedure was followed with the patient in maximum calcaneal eversion.

Measurements of inversion and eversion were recorded without referencing them to the STJN position. These measurements were later referenced from the STJN position. Suppose, for example, that the angle formed by the patient's leg and calcaneus in the STJN position is 3 degrees of varus, the angle of inver-

TABLE 1
Characteristics of Patient Sample

Variable	
Male	22
Female	28
Mean age (yr)	35.9 (s = 15.6)
Age range (yr)	12–81
Mean height (in[a])	66.5 (s = 4.2)
Height range (in)	58–74
Mean weight (lb[b])	157.40 (s = 29.1)
Weight range (lb)	102–210
Number of left feet measured	26
Number of right feet measured	24
Patient diagnoses	
Neurological[c]	13
Orthopedic	37

[a] 1 in = 2.54 cm.
[b] 1 lb = 0.4536 kg.
[c] Post-spinal cord injury, head trauma, cerebrovascular accident.

* Convacare, Inc, PO Box 19747, Raleigh, NC 27619.
† Model 7475A, Hewlett-Packard Co, 16399 W Bernardo Dr, San Diego, CA 92127-1899.
‡ 1 in = 2.54 cm.

sion is 20 degrees, and the angle of eversion is 2 degrees. However, when referenced to the STJN position, these last two values would be recorded as 17 degrees of inversion and 5 degrees of eversion.

After the three measurements (STJN position, inversion, and eversion) were taken, the line on the leg was thoroughly washed off. The patient stood up and was allowed to walk around. For 11 of the 13 patients who were neurologically involved and for 5 of the 37 patients with orthopedic diagnoses, passive circumduction of the foot and ankle was substituted because standing was either impractical or too painful. The patient was then repositioned in prone, new marks were made, and the angles were remeasured following the sequence described previously.

After all STJ measurements were taken, the therapist had the patient circumduct the foot and ankle once or twice. The therapist then positioned the patient and measured passive ankle dorsiflexion and plantar flexion with the blinded goniometer. For ankle PROM, both patient position and measurement technique was determined by the therapist taking the measurement. This procedure was repeated twice. Active (passive, if necessary) circumduction of the foot and ankle was performed between measurement sessions. Ankle PROM measurements could not be taken on one patient with a closed head injury because of patient restlessness. Therefore, in the portion of the study examining reliability of ankle PROM measurements 49 feet were measured.

After ankle and STJ measurements were taken and recorded, the patient was asked to stand up and walk around. The referring therapist left the examination area, after which the retest therapist entered the area and proceeded to position, mark, and measure the patient in the same sequence as the referring therapist.

Data Analysis

To describe the degree of agreement for the relationships identified in the research questions, we used the most conservative form of the ICC described by Shrout and Fleiss (formula 1,1).[3] Calculation of the ICC for intratester reliability was made by comparing the paired measurements taken by each tester (100 paired measurements for STJ PROM and STJN position and 98 paired measurements for ankle PROM, therefore, were obtained). Calculation of the ICC for intertester reliability was made by comparing the first measurements taken by each pair of testers (50 paired measurements of STJ PROM and STJN position and 49 paired measurements of ankle PROM, therefore, were obtained).

RESULTS

For intratester reliability for measurements of the STJN position, the ICC was .77. For unreferenced measurements of the STJ PROM, the ICC values for intratester reliability were .74 for inversion and .75 for eversion. When STJ PROM measurements were referenced from the STJN position, ICC values were .62 for inversion and .59 for eversion (Tab. 2).

For intertester reliability for measurements of the STJN position, the ICC was .25. The intertester ICC values for unreferenced STJ PROM measurements were .32 for STJ inversion and .17 for STJ eversion. When STJ PROM measurements were referenced from the STJN position, intertester ICC values were .15 for inversion and .12 for eversion (Tab. 3).

The ICC values for intratester reliability of ankle PROM measurements were .90 for dorsiflexion and .86 for plantar flexion (Tab. 2). The ICC values for intertester reliability were .50 for dorsiflexion and .72 for plantar flexion (Tab. 4).

DISCUSSION

Measurements of the STJN position and of STJ and ankle PROM appear to be fairly reliable when taken by the same therapist over a short period of time. The ICC values for STJ measurements were lower than those for the dorsiflexion and plantar flexion measurements and considerably lower than those reported by other authors for PROM measurements of the shoulder, elbow, wrist, hip, knee, and ankle joints.[6–8]

Referencing STJ PROM measurements to the STJN position consistently diminished reliability of the measurements (Tabs. 2, 3). This finding is not surprising considering the amount of

TABLE 2
Intratester Reliability for Ankle and Subtalar Joint (STJ) Passive Range of Motion (PROM) Measurements

Joint Position	Category	Number of Measurements	ICC[a]
STJN[b]	all subjects	100	.77
	patients with neurologic disorders	26	.75
	patients with general orthopedic disorders	74	.78
	more experienced therapists[c]	37	.88
Inversion	referenced to STJN position	100	.62
	unreferenced to STJN position	100	.74
	patients with neurologic disorders	26	.53
	patients with general orthopedic disorders	74	.79
	more experienced therapists[c]	19	.77
Eversion	referenced to STJN position	100	.59
	unreferenced to STJN position	100	.75
	patients with neurologic disorders	26	.65
	patients with general orthopedic disorders	74	.78
	more experienced therapists[c]	19	.72
Dorsiflexion	all subjects	98	.90
	patients with neurologic disorders	24	.95
	patients with general orthopedic disorders	74	.80
	more experienced therapists[d]	35	.91
Plantar flexion	all subjects	98	.86
	patients with neurologic disorders	24	.72
	patients with general orthopedic disorders	74	.89
	more experienced therapists[d]	35	.92

[a] Intraclass correlation coefficients were calculated by comparing the first and second measurements by each therapist.
[b] STJN = subtalar joint neutral.
[c] Therapists who stated they measured STJN position or STJ PROM more than once a month.
[d] Therapists who stated they measured ankle dorsiflexion and plantar flexion daily.

TABLE 3
Intertester Reliability of Subtalar Joint (STJ) Passive Range of Motion (PROM) Measurements

Joint Position	Category	Number of Measurements	ICC[a]
STJN[b]	all subjects	50	.25
	patients with neurologic disorders	13	.29
	patients with general orthopedic disorders	37	.22
	more experienced theapists[c]	6	.58
Inversion	referenced to STJN position	50	.15
	unreferenced to STJN position	50	.32
	patients with neurologic disorders	13	.45
	patients with general orthopedic disorders	37	.30
	more experienced therapists[c]	11	.51
Eversion	referenced to STJN position	50	.12
	unreferenced to STJN position	50	.17
	patients with neurologic disorders	13	0
	patients with general orthopedic disorders	37	.22
	more experienced therapists[c]	16	.28

[a] Intraclass correlation coefficients were calculated from the paired first measurements of each therapist.
[b] STJN = subtalar joint neutral.
[c] Therapists who stated they measured STJN position or STJ PROM more than once a month.

TABLE 4
Intertester Reliability for Ankle Passive Range of Motion Measurements

Joint Position	Category	Number of Measurements	ICC[a]
Dorsiflexion	all subjects	49	.50
	patients with neurologic disorders	12	.77
	patients with general orthopedic disorders	37	0
	more experienced therapists[b]	43	.54
Plantar flexion	all subjects	49	.72
	patients with neurologic disorders	12	.60
	patients with general orthopedic disorders	37	.74
	more experienced therapists[b]	30	.70

[a] Intraclass correlation coefficients were calculated from the paired first measurements of each therapist.
[b] More experienced therapists were those who stated that they measured ankle dorsiflexion and plantar flexion daily.

error associated with measuring STJN. Referencing STJ PROM from the STJN position compounds the amount of unexplained variance associated with both measurements. The results of our study suggest that if therapists follow Gray's[9] suggestion to reference STJ PROM measurements from the STJN position, they will add additional error to their measurements. In view of our data, we believe that measurements should not be referenced.

The intertester reliability for STJ PROM and ankle dorsiflexion was poor (Tabs. 3, 4). These findings are similar to the low ICC values authors have reported for PROM measurements of knee extension[6,7] and of shoulder extension, medial (internal) rotation, and horizontal abduction.[8] The poor reliability can be compared with the relatively high ICCs these same authors have reported for other PROM measurements of the wrist and ankle,[6] elbow and knee,[6,7] and shoulder.[8]

The poor intertester reliability for measuring the position of STJN is similar to what we found when we analyzed the data reported by Baldwin and Graebner.[1] As noted previously, these authors' data showed an absence of reliability for measurements of the STJN position when using either a K-square or goniometer.

When examining the data in our study, we noted that for 15 of the 50 paired measurements therapists did not even agree whether the rear foot was in a varus, valgus, or zero position when the foot was placed in the STJN position. As part of an a posteriori analysis, the numerical data (ie, the position of STJN) were converted into categorical data. We noted whether therapists thought the position of STJN was in a varus, valgus, or zero position. We then calculated a contingency coefficient[10] to determine the degree of agreement on the general position. The obtained value of .35 indicates poor intertester reliability for therapists even being able to agree on the general position the rear foot is in when it is placed in the STJN position.

The fair intratester reliability for measuring STJN position suggests that this measurement may be useful in certain instances. For example, repeated measurements of the STJN position might be used to determine whether serial casting is affecting a change in patients with soft tissue contractures of the foot and ankle.

The poor intertester reliability of measuring the STJN position is disturbing because of how often this measurement is used clinically. This position may be used to form a clinical impression and guide treatment such as the use of an orthosis or specialized shoes. Our study suggests that if two therapists were to evaluate the same patient using STJN measurements, they could administer different treatments. The treatments may even be designed to achieve opposite goals. For example, an orthosis with a medial post might be prescribed for a patient with a varus rear foot; conversely, an orthosis with a lateral post might be prescribed for someone with a valgus rear foot. However, our results indicate that two different therapists examining the same patient are not only likely to disagree on the angle of STJN, there is also a good possibility that they may not even agree on whether the STJN position was in a varus or valgus position.

Our data suggest that orthotic devices and specialized shoes, which often cost the patients hundreds of dollars, may be prescribed based on the use of an unreliable measurement. Other patients who might be helped greatly by the use of an orthosis may have found an orthosis not to be of any use because its design was based on an unreliable measurement. Based on our data, it would appear that when different therapists fabricate an orthosis for a patient based on the STJN position, they may be fabricating very different orthoses.

In view of the error associated with measuring the position of STJN, thera-

pists may want to reconsider the way in which they fabricate orthoses. Instead of fabricating orthoses based on the measurement of STJN, they may want to consider the effect of posting the rear foot in varying degrees of varus or valgus positions depending on the patient's symptoms. Then, based on the results of experimenting with different types of posting, a permanent orthosis can be fabricated.

A further consequence of poor intertester reliability for measuring STJN is that communication among clinicians is impeded. For example, studies that have either examined the STJN position in various subject groups or used it as a point of reference for taking other measurements, cannot be interpreted if their results are based on unreliable measurements.

The fair intratester reliability for STJ and ankle PROM measurements is clinically relevant. These measurements, when taken by the same therapist, may be useful when evaluating a patient (eg, comparing one foot to the other or evaluating the results of various treatments, such as joint mobilization).

The poor intertester reliability for ankle dorsiflexion and STJ PROM, like that for STJN position, has serious implications. Our data suggest that investigators using these measurements must address the issue of reliability, especially if more than one tester is involved.

The poor intertester reliability of ankle dorsiflexion and STJ PROM measurements may also help explain the highly divergent values reported by various authors concerning "normal" PROM values for these motions. This wide variability could reflect normal variation, but our data suggest it may also be a reflection of the error associated with the measurements.

A posteriori analyses were performed in an attempt to identify variables that may have affected the reliability of the measurements taken. As stated previously, ICC values for STJ PROM were generally lower than those observed for the ankle PROM in this study or for joints measured by other authors.[6-8] This finding could be due to the small excursion of the STJ. A few degrees of difference between STJ measurements represents a large percentage of the total range of movement, which could have had a dramatic effect on the ICCs.

The difficulty in taking the PROM measurements was another possible source of error. Therapists appeared to have had difficulty in maintaining the foot and ankle in the desired position. They had to use one hand to maintain the position and their other hand to use the goniometer.

The effect of patient diagnosis on intratester reliability of STJ measurements was not dramatic (Tab. 2). The ICC values for STJN are nearly identical for both patients with general orthopedic and neurological diagnoses. For measurements of inversion and eversion, intratester reliability was slightly better for patients with orthopedic disorders than for those with neurologic disorders. Perhaps the amount of passive resistance encountered by the therapists varied more for the patients with neurological disorders than for those with orthopedic disorders. Many of the patients with neurological disorders demonstrated abnormal postures or involuntary muscle contractions, or would become restless after a few minutes of lying on their stomach. Intertester reliability of STJ measurements was universally poor. The effect of patient diagnosis could not be evaluated fully (Tab. 3) because some subgroups contained too few patients to allow meaningful conclusions.

Patient diagnosis had an effect on the reliability of ankle dorsiflexion, especially intertester ICC values (Tab. 4). Pandya et al[6] did not describe the type of ICC they used; therefore, exact comparisons with our data are not possible. Our ICC values are close to the values they reported for measurements taken on patients with muscular dystrophy. Perhaps because patients with neurological disorders often exhibit plantar flexion contractures, they may have a more distinct or rigid end-feel in dorsiflexion than patients with muscular dystrophy. During measurement sessions, the therapists in this study appeared to exert a variable amount of force on the foot. This variability may have caused greater variability in measurements of flexible ankles as compared with the relatively inflexible ankles of patients with neurological disorders.

A posteriori analyses showed no consistent pattern to indicate that a second set of paired measurements between testers was more reliable than the first set of paired measurements (Tab. 5). The results also indicate that no meaningful improvement in intertester relia-

TABLE 5
Effect of Using Second Measurements and Means on Intertester Reliability

Joint Position	Category	Number of Measurements	ICC		
			1st[a]	2nd[b]	$\bar{X}$[c]
STJN[d]	all subjects	50	.25	.40	.39
Inversion	all subjects referenced to STJN	50	.15	0	.06
	all subjects unreferenced	50	.32	.13	.26
Eversion	all subjects referenced to STJN	50	.12	.05	.16
	all subjects unreferenced	50	.17	.21	.21
Dorsiflexion	all subjects	49	.50	.45	.50
Plantar flexion	all subjects	49	.72	.72	.77

[a] Intraclass correlation coefficients were calculated using the paired first measurements taken by each therapist.
[b] Intraclass correlation coefficients were calculated using the paired second measurements taken by each therapist.
[c] Intraclass correlation coefficients were calculated using the means of the first and second measurements taken by each therapist.
[d] STJN = subtalar joint neutral.

TABLE 6
Intertester Reliability for Ankle Passive Range of Motion when Subject Position Was the Same or Different for Paired Therapists

Joint Motion	Position	Number of Measurements	ICC[a]
Dorsiflexion	same	27	.40
	different	22	.59
Plantar flexion	same	27	.75
	different	22	.65

[a] Intraclass correlation coefficients were calculated from the first measurements taken by each therapist.

bility is found when therapists use the means of repeated measures (Tab. 5). This finding contrasts with those of Low[11] but supports the observations of Rothstein et al[7] and Boone et al.[12]

The results indicate that for ankle PROM, subject position was not a significant factor in affecting reliability between testers (Tab. 6). This finding contrasts with the findings of Rothstein et al,[7] who found that generally poor intertester reliability for measurements of knee extension could be dramatically improved if the same patient position was used by each tester.

Our study, in agreement with the findings of Rothstein et al[7] and Riddle et al,[8] suggests that reliability studies are needed for each joint and each motion. Factors that affect reliability in measuring PROM for one joint (eg, patient position) may not affect the reliability of measuring the PROM of other joints.

The cause of the poor intertester reliability for taking ankle and STJ measurements could not be determined from our study. However, the results strongly suggest that repeated measurements of these joints should be taken by the same therapist.

CONCLUSIONS

Clinical measurements of the STJN position, as used in this study, can be moderately reliable if taken by the same examiner over a short period of time. However, because of how this measurement is used and in light of the poor intertester reliability, the clinical usefulness of measuring the position of STJN is limited.

Clinical measurements of STJ and ankle PROM may also be moderately reliable if taken by the same therapist over a short period of time. Referencing these measurements to the STJN position, however, will diminish their reliability.

Clinical measurements of STJN and STJ PROM, as taken in this study, cannot be considered to be reliable between testers. Clinical measurements of passive ankle plantar flexion may be moderately reliable between testers, whereas the reliability of measurements of dorsiflexion between testers may be dependent on patient diagnosis.

Therapists who measure STJ and ankle PROM should be aware of the error associated with these measurements, and when possible, one therapist should take all repeated measurements. Therapists who measure the position of STJN should realize that considerable error exists in this measurement, and clinical decisions based on the use of this measurement must be seriously reconsidered.

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