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The reproducibility of an isokinetic testing technique at the ankle joint

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Abstract. The purpose of this study was to determine the reproducibility of measurements derived from a plantar flexion and dorsiflexion isokinetic test protocol. Recreationally active men ($n = 8$) and women ($n = 18$) were seated in 30° of trunk flexion and full knee extension (0° of knee flexion) and performed three concentric and eccentric dorsiflexion and plantar flexion movements at the speeds of 30°/s and 120°/s on two different occasions. Peak torque (PT) and average torque (AT) measurements were obtained and compared across the two sessions. Intra-class correlation coefficient (ICC's) values indicated acceptable reproducibility for the concentric and eccentric PT and AT values of dorsiflexion (range from 0.77–0.93) and plantar flexion (range from 0.78–0.95). The corresponding Standard Error of Measurement (SEM) values indicated a good level of measurement precision. These findings suggest that this isokinetic test protocol involving an extended knee position for isolating PF and DF ankle motions produces reliable measurements. This test protocol offers a viable alternative to traditional test positions used to assess isokinetic strength in the ankle joint.

Keywords: Dorsiflexion, dynamometer, plantar flexion, torque

1. Introduction

Isokinetic strength is the force generated by a muscle against a resistance at a constant rate of movement [16]. Methods of isolating and measuring isokinetic strength at the ankle joint can serve as a screening tool for injury severity, determining return-to-play status, and conducting research [3]. The subject positioning during an isokinetic testing protocol of this joint is not universal and few authors have compared different positional arrangements [2,3,11,12,17,18].

Most studies that have assessed isokinetic strength at the ankle joint place subjects in a supine position [2,8], however seated, prone, and standing protocols have also been examined [11,13,14,17,19]. Variability also exists with respect to the amount of hip and knee flexion. For example, Fugl-Meyer et al. [2,3] found that in the case of ankle plantar flexion, peak torques were greater at 0° than at 90° of knee flexion. Considering that the gastrocnemius is a biarticulate muscle, plantar flexion torques should logically be affected by these changes in knee joint position. In addition, placing the subject in a more upright position with a certain degree of hip flexion as opposed to that of 0° has been described as a more *functional* testing arrangement [12].

The purpose of the current study was to evaluate the test-retest reproducibility of isokinetic torque measurements derived from a Kin Com dynamometer with the subject in 30° of hip flexion and 0° of knee flexion for the motions of ankle plantar flexion (PF) and dorsiflexion (DF). Our intent was to develop a protocol that would isolate/incorporate the muscle groups responsible for ankle dorsiflexion and plantar flexion in the sagittal plane, while the subjects performed the motions in a seated (more functional) test position. Overriding this general aim was our desire to provide evidence for a reliable measurement protocol for both the research and clinical settings.

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2. Materials and methods

2.1. Subjects

Twenty-six healthy men and women volunteered to participate in this study. The subjects consisted of eight males (age 23.8 ± 7.6 yr., height 175.9 ± 3.7 cm, mass 78.2 ± 10.5 kg) and eighteen women (age 19.9 ± 2.7 yr., height 166.6 ± 6.7 cm, mass 62.6 ± 7.9 kg). All subjects were in good health with no history of previous injury that currently affected their activity level. This project was approved by the Humans Subjects Review Board of the university (HS 05-194) and subjects gave written informed consent prior to participating.

2.2. Instrumentation

The Kinetic Communicator (Kin Com) 125 AP (Chattanooga Group, Chattanooga, TN) isokinetic dynamometer, integrated with a computer and appropriate software, was used to assess both average (AT) and peak torque (PT). The reliability of this device in the testing of ankle strength has been previously established [7]. The dynamometer was programmed to move at a constant velocity with medium acceleration and deceleration and was calibrated before each session.

2.3. Isokinetic testing procedure

A five-minute warm-up consisting of moderate-intensity stationary bicycling preceded the isokinetic activity. Subjects were also allowed to perform a series of lower extremity flexibility exercises. After the warm-up and stretching exercises were completed, the participants were acquainted with the testing protocol.

Participants were stabilized in the chair according to the manufacturer's guidelines, with straps securing the chest and the waist. The seat back angle was set at 60° in order to maintain an appropriate amount of hip flexion (30°); a position that was confirmed using a handheld goniometer. This test position also afforded those with tight hamstring musculature to remain comfortably seated in the chair and execute the protocol without difficulty. The foot was then positioned in the plantar flexion/dorsiflexion footplate and the Kin Com moved to the appropriate position using the automatic positioning ("AP") function. This included considerations for seat and dynamometer height, as well as the axis of joint motion through the talocrural joint. The knee joint was placed in full extension (0° of knee flexion) and confirmed using a handheld goniometer. A universal stabilizer was used to position and hold the thigh to the dynamometer chair to prevent any unwanted muscle substitutions (Fig. 1). The foot was securely fastened into the footplate attachment using hook-and-loop closures. With the foot securely fastened into the footplate, the subject's available range-of-motion (ROM) was determined using the built-in electrogoniometer on the Kin Com. The start and stop angles were then set based on the subject's physiological range-of-motion parameters. To ensure consistency in testing, PF strength was assessed with the subjects starting from 10° of ankle DF and moving into 35° of PF for a total range of 45°. Conversely, DF strength was assessed with the subjects starting from 35° of ankle PF and moving into 10° of DF.

Fig. 1. Patient positioned on the Kin Com isokinetic dynamometer for PF and DF testing.

The gravity-correction procedure described in the Kin Com manual was performed to ensure accurate data collection. The start forward (preload) force for concentric muscle action was set at 100/150 N in plantar flexion and 50 N in dorsiflexion. This represents the minimal force required to initiate movement of the lever arm in the forward direction [9]. The start backward force for eccentric muscle action was set at 150/200 N for plantar flexion and 50 N for dorsiflexion. This represents the minimal force required to initiate movement of the lever arm in the backward direction [9].

Both feet were tested, with the starting foot decided randomly via a coin toss. Furthermore, the movement to be tested (PF vs. DF) was randomly assigned using a second coin toss. Using the overlay feature of the Kin Com software, each subject was tested at isokinetic velocities of 30°/sec and 120°/sec. This feature enables the concentric and eccentric muscle actions for each ankle motion to be executed individually with a pause between test repetitions to prohibit the stretch-shortening phenomenon from occurring. A total of three concentric and eccentric test repetitions were completed. Subjects were instructed to provide maximal effort with each repetition and were given visual feedback from the Kin Com computer screen as well as verbal encouragement. After both ankle motions were tested, the protocol was repeated using the opposite side. At the conclusion of testing subjects were instructed to stretch and cool down.

The subjects were then asked to return for testing in seven days. The order of testing was identical for the second day and the procedures performed in the same manner as described above.

2.4. Statistical analysis

SPSS 13.0 for Windows (SPSS Inc., Chicago, IL) statistical software was used for all data analyses. Test-retest measurement reproducibility of PT and AT in Newton-meters (Nm) was expressed as: a) mean and standard deviation (SD) of the differences between measurements, b) 95% confidence interval (CI), and c) intra-class correlation coefficient (ICC). The ICC ranges from 0 (no agreement) to +1 (perfect agreement). The Standard Error of Measurement (SEM) was calculated using the following equation: $\text{SEM} = \text{SD}\sqrt{(1\text{-ICC})}$, where SD refers to the standard deviation of the combined test and retest measurements. For comparisons of systematic differences within subjects between sides, paired t-tests were also used. An *a-priori* level of significance was set at $P < 0.05$ for all comparisons.

3. Results

Concentric and eccentric torque comparisons across the two testing days are revealed in Tables 1 through 4. Intraclass correlation coefficient (ICC) values for plantar flexion ranged from 0.77–0.93, while values for dorsiflexion ranged from 0.78–0.95. The corresponding SEM values indicated a very good level of measurement precision. The isokinetic descriptive statistics and comparisons between the right and left sides of the subjects are located in Tables 5 and 6. There were no significant differences in PT or AT isokinetic strength measurements between sides for either plantar flexion ($P = 0.17$) and dorsiflexion ($P = 0.75$).

4. Discussion

For isokinetic dynamometry, four major factors are likely to influence the overall results: the accuracy of the dynamometer, the test protocol, the reproducibility of the measurement parameters, and subject-related factors [5]. The present study concentrated on the reproducibility of test measurements taken from a novel and unique test protocol involving ankle plantar and dorsiflexion.

The principal finding of the present study was that the test-retest reproducibility was acceptable for the testing method employed. Based on previous research [8, 12–14] that has evaluated the reliability of isokinetic testing positions at the ankle joint, our ICC value range of 0.77–0.95 is greater than the combined average of those studies. With the reproducibility of this isokinetic testing procedure reaching a high level of agreement between test sessions and an excellent rating based on the Fleiss benchmarks [1], there is strong support for the use of this protocol. We are confident that the careful attention we directed toward individual patient set-up with each subsequent test day and the reliance on the automatic positioning (AP) function of the Kin Com isokinetic dynamometer are accurately reflected in the measurement reproducibility afforded us. Because relative reproducibility scores fail to reveal, in quantitative terms, how much of a change in the measured scores is real and how much should be attributed to error, using SEM indices provides the reader with a more precise or absolute measure of reproducibility [15]. As a consequence we have reported the SEM values for our isokinetic measurements and these values revealed excellent precision of measurement. Additionally, because these values carry the same units as the mean isokinetic torque measures, it makes it easier for the clinician to appreciate the changes across test days. Prushansky and colleagues suggest that these SEM values can subsequently be used to delineate measurement error from a genuine clinical change [15]. Kaminski and Dover add that the SEM is a reflection of the consistency of the test protocol and proficiency of the examiner in performing the test sequence [6]. Interestingly, the plantar

Table 1
Plantar flexion isokinetic strength (Nm) for the right ankle on testing days 1 and 2. **PT** peak torque, **AT** average torque, **Con** concentric muscle action, **Ecc** eccentric muscle action ($n = 26$)

Muscle Action, Speed, Torque Measurement	Test 1 Mean (SD)	Test 2 Mean (SD)	Test 2-1 Mean (SD)	95 % CI	P-value	ICC Value	SEM (% relative to mean score)
Con 30°/s PT	149.73 (52.75)	150.77 (51.95)	1.04 (0.539)	−12.51 to 10.43	0.854	0.921	14.76 (9.8%)
Con 120°/s PT	92.87 (41.20)	92.35 (38.86)	−0.462 (0.107)	−11.35 to 12.27	0.936	0.846	15.85 (17.1%)
Con 30°/s AT	106.19 (36.67)	102.19 (35.16)	−4.00 (8.00)	−5.04 to 13.04	0.371	0.892	11.70 (11.2%)
Con 120°/s AT	66.31 (26.63)	65.81 (27.64)	0.50 (0.125)	−5.99 to 6.99	0.875	0.904	9.03 (13.7%)
Ecc 30°/s PT	240.00 (81.57)	234.65 (81.31)	−5.35 (14.29)	−15.00 to 25.69	0.593	0.894	25.38 (10.7%)
Ecc 120°/s PT	208.35 (75.32)	199.81 (75.93)	−8.53 (36.45)	−6.60 to 23.68	0.256	0.928	19.19 (9.4%)
Ecc 30°/s AT	152.85 (45.18)	145.12 (46.42)	−7.73 (29.88)	−4.08 to 19.54	0.190	0.897	14.08 (9.5%)
Ecc 120°/s AT	129.58 (42.39)	126.46 (43.61)	−3.12 (4.85)	−9.09 to 15.32	0.604	0.859	15.22 (11.9%)

Table 2
Dorsiflexion isokinetic strength (Nm) for the right ankle on testing days 1 and 2. **PT** peak torque, **AT** average torque, **Con** concentric muscle action, **Ecc** eccentric muscle action, ($n = 26$)

Muscle Action, Speed, Torque Measurement	Day 1 Mean (SD)	Day 2 Mean (SD)	Day 2-1 Mean (SD)	95 % CI	P-value	ICC Value	SEM (% relative to mean score)
Con 30°/s PT	39.77 (15.81)	44.12 (14.17)	4.35 (9.45)	−8.26 to −0.43	0.031	0.884	4.58 (10.9%)
Con 120°/s PT	25.65 (10.30)	28.46 (9.76)	2.81 (3.94)	−5.85 to 0.23	0.069	0.836	4.51 (16.7%)
Con 30°/s AT	32.69 (12.59)	35.65 (12.49)	2.96 (0.956)	−5.99 to 0.07	0.055	0.902	3.96 (11.6%)
Con 120°/s AT	16.46 (8.09)	19.92 (8.66)	3.46 (5.99)	−6.36 to −0.56	0.021	0.775	4.02 (22.1%)
Ecc 30°/s PT	61.88 (20.94)	67.19 (19.38)	5.31 (14.09)	−9.09 to −1.53	0.008	0.943	4.81 (7.5%)
Ecc 120°/s PT	62.46 (18.86)	67.88 (19.82)	5.42 (14.71)	−9.53 to −1.32	0.012	0.926	5.26 (8.1%)
Ecc 30°/s AT	52.27 (17.66)	57.23 (17.74)	4.96 (12.31)	−8.01 to −1.92	0.003	0.953	3.84 (7.0%)
Ecc 120°/s AT	47.96 (14.74)	51.73 (16.68)	3.77 (7.10)	−7.27 to −0.27	0.036	0.918	4.50 (9.0%)

flexion SEM values had an average of 11.3% relative to the mean score, while the dorsiflexion SEM values demonstrated an average of 11.6% relative to the mean score. Examining changes between test days in this manner further clarifies for the reader and clinician the small amount of change in isokinetic torque and adds credence to the reproducibility of the testing protocol.

In a study similar to ours, Holmback et al. [5] examined test-retest reproducibility of isokinetic ankle dorsiflexor strength measurements in young healthy adults. They determined that the dorsiflexor peak torque measurements across five different test velocities were highly reliable, with ICC values ranging from 0.61 to 0.93. Subsequently, they reported SEM values ranging from 1.69–2.16 Nm, and recommended that test-retest reliability analyses include the ICC and assessments of measurement errors such as the SEM [5]. They also suggested using graphic representations of the isokinetic measurements to further delineate any systemic variations in the data [5]. Kaminski and Dover established the reproducibility of isokinetic measurements derived from the Biodex System 3 (Biodex Medical Systems, Shirley, NY) dynamometer and the ability of this device to reproduce concentric inversion and eversion peak and average torque [6]. They reported good to excellent reproducibility coefficients that were

Table 3
Plantar flexion isokinetic strength (Nm) for the left ankle on testing days 1 and 2. **PT** peak torque, **AT** average torque, **Con** concentric muscle action, **Ecc** eccentric muscle action, ($n = 26$)

Muscle Action, Speed, Torque Measurement	Day 1 Mean (SD)	Day 2 Mean (SD)	Day 2-1 Mean (SD)	95 % CI	P-value	ICC Value	SEM (% relative to mean score)
Con 30°/s PT	144.27 (36.19)	152 (48.6)	7.73 (29.88)	−19.69 to 4.23	0.195	0.864	15.71 (10.6%)
Con 120°/s PT	88.85 (33.15)	91.5 (29.23)	2.65 (3.52)	−12.19 to 6.89	0.572	0.833	12.66 (14.0%)
Con 30°/s AT	103.85 (26.04)	104.54 (34.89)	0.692 (0.24)	−8.75 to 7.37	0.861	0.883	10.43 (10.0%)
Con 120°/s AT	61.77 (22.63)	65.27 (20.07)	3.50 (6.13)	−10.61 to 3.61	0.320	0.796	9.60 (14.3%)
Ecc 30°/s PT	245.54 (84.85)	233.42 (79.64)	−12.12 (73.39)	−6.98 to 31.21	0.203	0.910	24.51 (10.2%)
Ecc 120°/s PT	228.23 (73.85)	222.31 (72.54)	−5.92 (38.5)	−9.62 to 21.47	0.44	0.926	19.73 (8.8%)
Ecc 30°/s AT	156.50 (47.15)	145.69 (46.59)	−10.81 (58.40)	−0.65 to 22.27	0.063	0.899	14.85 (9.9%)
Ecc 120°/s AT	131.46 (36.90)	123.31 (31.96)	−8.15 (33.24)	−1.39 to 17.70	0.091	0.867	12.56 (9.9%)

Table 4
Dorsiflexion isokinetic strength (Nm) for the left ankle on testing days 1 and 2. **PT** peak torque, **AT** average torque, **Con** concentric muscle action, **Ecc** eccentric muscle action, ($n = 26$)

Muscle Action, Speed, Torque Measurement	Day 1 Mean (SD)	Day 2 Mean (SD)	Day 2-1 Mean (SD)	95 % CI	P-value	ICC Value	SEM (% relative to mean score)
Con 30°/s PT	43.46 (13.52)	40.96 (13.50)	−2.5 (3.13)	−0.97 to 5.97	0.15	0.888	4.50 (10.7%)
Con 120°/s PT	28.77 (11.02)	25.88 (11.26)	−2.89 (4.16)	0.22 to 5.55	0.035	0.904	3.45 (12.6%)
Con 30°/s AT	35.65 (11.54)	33.42 (10.20)	−2.23 (2.49)	−1.05 to 5.52	0.174	0.838	4.36 (12.6%)
Con 120°/s AT	19.42 (8.76)	17.38 (9.33)	−2.04 (2.08)	−0.44 to 4.51	0.102	0.870	3.25 (17.7%)
Ecc 30°/s PT	66.38 (17.47)	64.81 (18.10)	−1.58 (1.24)	−2.49 to 5.65	0.433	0.913	5.20 (7.9%)
Ecc 120°/s PT	66.38 (17.20)	64.35 (15.94)	−2.04 (2.08)	−2.23 to 6.31	0.335	0.887	5.53 (8.5%)
Ecc 30°/s AT	54.69 (17.94)	55.27 (15.09)	0.58 (0.17)	−5.33 to 4.17	0.804	0.856	6.23 (11.3%)
Ecc 120°/s AT	50.62 (15.87)	49.23 (12.05)	−1.39 (0.96)	−3.10 to 5.87	0.531	0.816	5.99 (12.0%)

calculated for both PT and AT measurements at each speed and motion tested [6]. Although they tested a different ankle motion from what we report here, their associated SEM values ranged from 1.23 Nm to 6.38 Nm. They did not report percentage of the mean values; however we calculated them based on their tabled data and found averages of 13.1% relative to the mean PT score and 15.3% relative to the mean AT score. These values are slightly higher than the averages we report in this paper, but are still considered acceptable.

Other support can be found in the literature regarding the influence of hip and knee angles in torque production at the ankle joint. As stated earlier, Fugl-Meyer et al. [2,3] and others [17] found that in the case of plantar flexion of the ankle joint, peak torques were greater at 0° rather than at 90° of knee flexion. Of note, the muscles that plantar flex the ankle are the three main muscles of the triceps surae complex (medial and lateral gastrocnemii and soleus) together with the plantaris, tibialis posterior, peroneus longus, peroneus brevis, and the long flexors of the toes. Of these, the triceps surae complex is considered to make the greatest contribution [17]. Since the gastrocnemii arise from the femoral condyles, the strength of this complex should be logically influenced whether the knee is in a position of flexion or extension during isokinetic

Table 5
Plantar flexion isokinetic strength (Nm) at the ankle joint for right and left sides, **PT** peak torque (Nm), **AT** average torque (Nm), **Con** concentric muscle action, **Ecc** eccentric muscle action, ($n = 26$)

	Right mean (SD)	Left mean (SD)	Left – Right mean (SD)	P-value
Con 30°/s PT	150.3 (50.4)	148.1 (40.2)	−2.1 (20.0)	0.594
Con120°/s PT	92.6 (37.3)	90.2 (28.9)	−2.4 (22.3)	0.588
Ecc 30°/s PT	237.3 (77.4)	239.5 (78.8)	+2.2 (34.2)	0.751
Ecc 120°/s PT	204.1 (70.1)	225.3 (70.6)	+21.2 (77.0)	0.173
Con 30°/s AT	104.2 (29.1)	104.2 (34.1)	0.0 (15.2)	1.00
Con 120°/s AT	66.1 (25.9)	63.5 (19.5)	−2.5 (14.9)	0.394
Ecc 30°/s AT	148.9 (43.4)	151.1 (44.7)	+2.1 (21.2)	0.615
Ecc 120°/s AT	129.9 (39.8)	127.4 (32.4)	−2.6 (19.5)	0.511

Table 6
Dorsiflexion isokinetic strength (Nm) at the ankle joint for right and left sides. **PT** peak torque, **AT** average torque, **Con** concentric muscle action, **Ecc** eccentric muscle action, ($n = 26$)

	Right mean (SD)	Left mean (SD)	Left – Right mean (SD)	P-value
Con 30°/s PT	41.9 (14.2)	42.2 (12.8)	−0.27 (8.3)	0.870
Con120°/s PT	27.1 (9.3)	27.3 (10.6)	−0.27 (9.4)	0.885
Ecc 30°/s PT	65.6 (18.1)	64.54 (19.6)	+1.1 (8.5)	0.901
Ecc 120°/s PT	65.2 (18.7)	65.4 (15.7)	+0.19 (8.4)	0.908
Con 30°/s AT	34.2 (11.9)	34.5 (10.1)	−0.37 (6.9)	0.788
Con 120°/s AT	18.2 (7.6)	18.4 (8.5)	−0.21 (6.9)	0.877
Ecc 30°/s AT	54.8 (17.3)	54.9 (15.5)	+0.23 (9.3)	0.900
Ecc 120°/s AT	49.8 (15.1)	49.9 (12.9)	+0.10 (8.5)	0.963

testing at the ankle. This also provides support for the previous findings indicating a torque increase when the leg is positioned in 0° of knee flexion [3,4,17].

Research has also discussed the influence that knee joint positioning has on the amount of tibial internal and external rotation occurring during isokinetic testing at the ankle joint [8]. When the knee is in flexion, some consider this a "loose-packed' position of the knee, where a greater degree of tibial rotation is available. Diminished accessory rotary motion occurs in the "close-packed' position of knee extension [10]. Isokinetic testing of plantar flexion and dorsiflexion at the ankle in the sagittal plane while the knee is flexed, may allow the knee flexors and other tibial rotators to influence the amount of torque that is generated.

The amount of hip or trunk flexion and the influence it has on ankle isokinetic strength has not been directly evaluated. However, placing a subject in hip flexion during isokinetic testing has been described as a providing a more functional testing position than that of a supine position [12]. We chose to place our subjects in 30° of hip flexion because it created a more functional position than 0° of hip flexion and also allowed subjects with less hip extension range-of-motion to maintain comfort throughout the protocol.

In addition to the measurement reproducibility of this positioning across testing days, we also reported no significant differences in torque production for the right and left sides within subjects. Differences have been reported in previous research [2,13], but have provided no explanation for the side differences. We feel that this further supports the consistency that can be obtained from this isokinetic protocol.

5. Conclusion

We conclude that ankle plantar flexion and dorsiflexion strength can be reliably assessed using this isokinetic testing position. Additionally, the manner in which our results are reflected and discussed is more in line with more contemporary reports involving measurement reproducibility and should allow future researchers to mimic our data analysis strategies. This can enable future research of this joint complex by providing consistency, while ensuring function and isolating the proper muscles for isokinetic strength testing.

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