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# Test–Retest Reliability of Biodex System 4 Pro for Isometric Ankle-Eversion and -Inversion Measurement

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***Context:*** The lack of knowledge about isometric ankle testing indicates the need for research in this area. ***Objective:*** to assess test–retest reliability and to determine the optimal position for isometric ankle-eversion and -inversion testing. ***Design:*** Test–retest reliability study. Isometric ankle eversion and inversion were assessed in 3 different dynamometer foot-plate positions: 0°, 7°, and 14° of inversion. Two maximal repetitions were performed at each angle. Both limbs were tested (40 ankles in total). The test was performed 2 times with a period of 7 d between the tests. ***Setting:*** University hospital. ***Participants:*** The study was carried out on 20 healthy athletes with no history of ankle sprains. ***Main Outcome Measures:*** Reliability was assessed using intraclass correlation coefficient ($ICC_{2,1}$); minimal detectable change (MDC) was calculated using a 95% confidence interval. Paired *t* test was used to measure statistically significant changes, and $P < .05$ was considered statistically significant. ***Results:*** Eversion and inversion peak torques showed high ICCs in all 3 angles (ICC values .87–.96, MDC values 3.09–6.81 Nm). Eversion peak torque was the smallest when testing at the 0° angle and gradually increased, reaching maximum values at 14° angle. The increase of eversion peak torque was statistically significant at 7 ° and 14° of inversion. Inversion peak torque showed an opposite pattern—it was the smallest when measured at the 14° angle and increased at the other 2 angles; statistically significant changes were seen only between measures taken at 0° and 14°. ***Conclusions:*** Isometric eversion and inversion testing using the Biodex 4 Pro system is a reliable method. The authors suggest that the angle of 7° of inversion is the best for isometric eversion and inversion testing.

***Keywords:*** isometric ankle testing, ankle-eversion testing, ankle-inversion testing, ankle positioning for isometric testing, ankle testing with the Biodex system

Ankle sprains remain one of the most common sports injuries.[1] Recovery may take weeks to months, and without proper treatment these injuries may lead to various complications including ankle instability or even arthrosis.[1] The main symptoms are pain, swelling, and instability. There is also a decrease in ankle-evertor and -invertor muscle strength due to impaired neuromuscular regulation. Neuromuscular regulation consists of proprioception, muscle strength, muscle reaction time, and postural control.[2] These muscle groups are responsible for functionally stabilizing the joint, and measurement of ankle-eversion and -inversion strength gives a better understanding of the functional state of the ankle after ankle sprain.[2,3]

Various researchers[4,5] have performed isokinetic testing to investigate eversion and inversion strength's relation to various conditions such as chronic ankle instability. They concluded that the possible cause of chronic ankle instability was a combination of diminished proprioception and evertor-muscle weakness.

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Nonetheless, isokinetic tests cannot be applied in early stages after acute ankle sprains, because eversion and inversion movements can affect the already injured ligaments. In these cases, isometric testing can be applied with adequate precautions. During isometric testing there is no movement, and this enables measurement of eversion and inversion strength without stressing injured ligaments.

Very few studies have investigated isometric testing. One study[6] investigated isokinetic, isotonic, and isometric plantar-flexion and dorsiflexion testing. Those authors concluded that isometric testing was the least reliable for this pattern. Another study[7] investigated isometric ankle-eversion and -inversion measurement at 0°. The authors found no significant differences between healthy patients and those with chronic ankle instability. Neither of the studies used isometric testing for patients with acute ankle sprains.

A few studies[8–10] investigated test–retest reliability of the Biodex dynamometer. The researchers concluded that it was a reliable tool for knee and ankle plantar-flexion and dorsiflexion isokinetic strength assessment. There is a lack of investigation of isometric eversion and inversion testing. The purpose of this study was to assess test–retest reliability of isometric ankle-eversion and -inversion testing, which could be applied for testing patients with acute ankle sprains.

# Materials and Methods

## Subjects

This study included 20 athletes, mean age 27.30 ± 4.91 years, mean height 185.5 ± 10.84 cm, mean weight 84.30 ± 14.22 kg, and mean body-mass index 23.49 ± 1.74. The inclusion criteria were age 18 to 30 years, no history of ankle sprains, and regular exercising (1–2 h/d of aerobic exercise, at least 4 d/wk).

This study was approved by the regional ethics committee (no. BE-2-33). All participants signed informed-patient consent forms.

## Isometric Testing

We used the Biodex System 4 Pro dynamometer and Biodex Advantage software package (Biodex Medical Systems Inc, Shirley, NY) to measure isometric ankle-eversion and -inversion peak torque. Subjects were tested in a semisupine position with extended knee. All subjects wore their own flat shoes; each shoe was fastened to the footplate of the dynamometer with 2 straps. To stabilize the subject's position, one strap was wrapped around the subject's thigh and the other strap around the waist (Figure 1).

## Protocol

Before testing each subject had to perform a 5-minute warm-up on a stationary bicycle with low resistance (50 W) at average pedaling speed (60–70 rpm). After 5 minutes of warm-up, the patient was positioned on the dynamometer chair. The range of motion was set to 15° of eversion and 20° of inversion. Each subject received verbal explanation of the test and could perform 3 isokinetic and 3 isometric submaximal repetitions of eversion and inversion with visual biofeedback on the screen.

To assess reliability, the test was performed at 3 different dynamometer foot-plate positions—neutral position of 0°, then at 7° of inversion, and at 14° of inversion (Figure 2). Neutral position of 0° was adjusted by using a spirit level, because at 0° the top of the dynamometer foot plate is horizontal. Such angles were chosen because in the natural ankle range of motion, inversion is greater than eversion. The midrange of motion is approximately at 7° of inversion. The dynamometer settings allow measurement of eversion and inversion only at the same

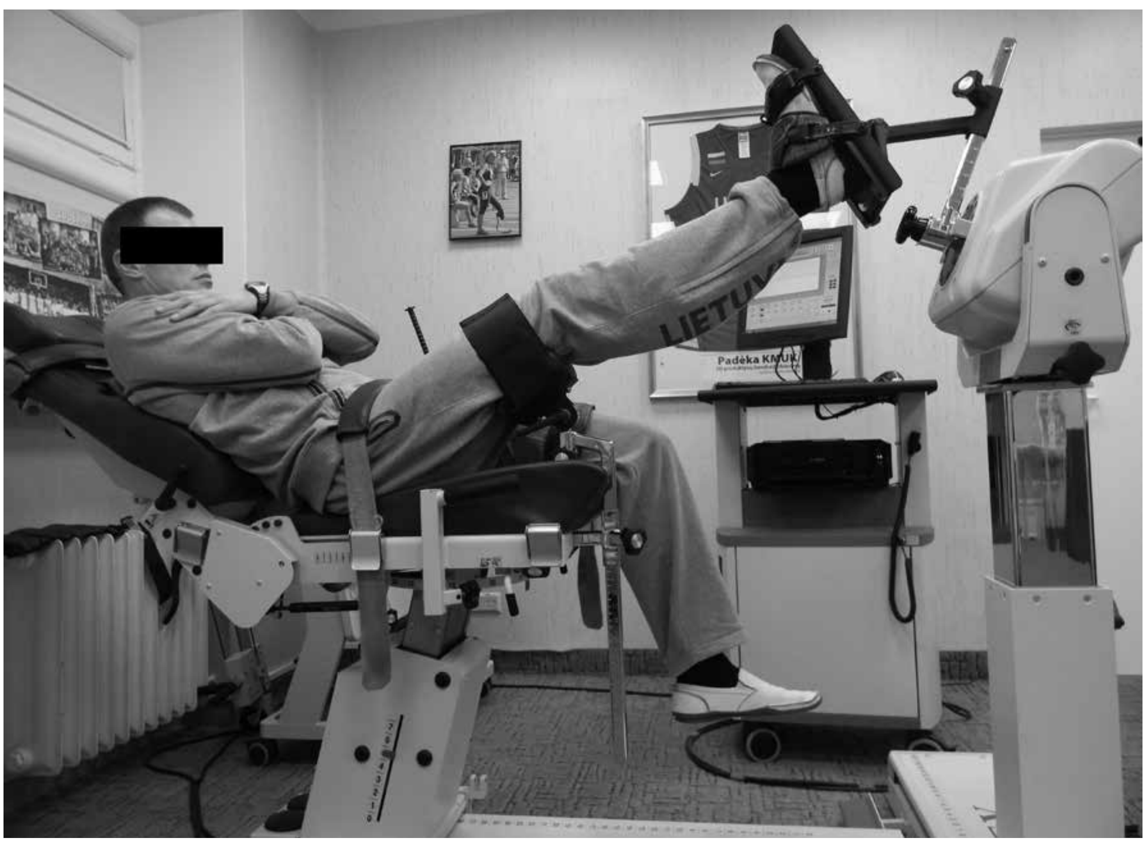

**Figure 1** — Patient positioning on the dynamometer.


**Figure 2** — Dynamometer footplate position set at 7° of inversion (view from above).

foot-plate angle, so we wanted to determine the best angle for isometric testing that would be the most representative of both eversion and inversion.

For this study we created a new testing protocol. At each angle subjects had to perform 2 maximal repetitions of isometric eversion and inversion. They had 7 seconds at each repetition to reach peak torque, which was measured when the torque curve reached its plateau. There was a rest period of 10 seconds between eversion and inversion contractions and a 30-second rest period between different foot-plate angles.

### Main Outcome Measures

We measured peak torque of each isometric eversion and inversion contraction. Reliability was assessed using intraclass correlation coefficient ($ICC_{2,1}$), standard error of measurement (SEM), and minimal detectable change ($MDC_{95}$).

### Study Protocol

Both the left and the right limb were tested (40 ankles in total). The test was performed 2 times with a period of 7 days between the tests.

## Statistics and Data Analysis

Descriptive data are presented as mean and SD. The Statistical Package for the Social Sciences (SPSS) for Windows (version 17.0) was used for statistical analysis. Reliability was assessed using $ICC_{2,1}$, and SEM. The MDC was calculated by multiplying the $z$-score corresponding to the level of significance of 95% (1.96), the square root of 2, and the SEM. The paired $t$ test was used to measure statistically significant changes between measures taken at different angles, and $P < .05$ was considered statistically significant.

## Results

Eversion and inversion peak-torque test–retest results showed high ICCs in all 3 angles.

Eversion peak torque was the smallest when testing at the 0° angle and gradually increased, reaching maximum values at the angle of 14°. The increase of eversion peak torque was statistically significant at 7° ($t_{39} = -2.7$, $P = .01$) and 14° of inversion ($t_{39} = -2.3$, $P = .02$).

Inversion peak torque showed the opposite pattern—it was the smallest when measured at the 14° angle and increased at the other 2 angles. Statistically significant changes were seen only between measures taken at 0° and 14° ($t_{39} = 8.5$, $P < .01$). All results are shown in Table 1.

## Discussion

The purpose of this study was to assess test–retest reliability of isometric ankle-eversion and -inversion testing, which could be applied to test patients with acute ankle sprains. In early stages of ankle sprains there usually is swelling, a diminished range of motion, and painful ankle movement, so isokinetic testing would not be recommended, because eversion and inversion movements would put additional stress to the already injured ligaments. In our experience, isometric testing, carried out with adequate precautions, is a safe and useful tool to monitor the functional state of the ankle after acute ankle sprains.

Our main findings show that by using the Biodex 4 Pro System isometric eversion and inversion strength can be measured reliably at all 3 dynamometer foot-plate angles. However, results at 14° of inversion showed the greatest eversion peak torque but the smallest inversion peak torque. It would better represent eversion. In addition, 14° of inversion might be an uncomfortable testing position for patients with acute ankle sprains.

Results at 0° show the greatest inversion peak torque but the smallest eversion peak torque. It would better represent inversion.

Testing results at 7° of inversion best represented both eversion and inversion—eversion was statistically significantly greater than at the angle of 0°; inversion had no statistically significant difference from inversion at 0°. Testing results at 7° of inversion also showed higher ICC and smaller SEM and $MDC_{95}$ values than those at

**Table 1 Summary of Outcomes**

| | 0° | 7° | 14° |
|---|---|---|---|
| First measurement | | | |
| eversion peak torque, Nm | 30.33 ± 6.26 | 34.27 ± 6.67 | 37.82 ± 7.05 |
| inversion peak torque, Nm | 31.58 ± 6.98 | 29.26 ± 5.62 | 27.23 ± 5.12 |
| Second measurement (after 1 wk) | | | |
| eversion peak torque, Nm | 29.70 ± 5.76 | 33.84 ± 6.43 | 37.39 ± 7.06 |
| inversion peak torque, Nm | 31.69 ± 6.39 | 28.94 ± 6.53 | 26.76 ± 5.90 |
| Eversion ICC (95% *CI*) | .869 (.767–.928) | .926 (.866–.960) | .952 (.912–.974) |
| Eversion SEM, Nm | 2.17 | 1.78 | 1.55 |
| Eversion $MDC_{95}$, Nm | 6.03 | 4.94 | 4.28 |
| Inversion ICC (95% *CI*) | .865 (.758–.926) | .905 (.827–.948) | .959 (.923–.979) |
| Inversion SEM, Nm | 2.46 | 1.87 | 1.12 |
| Inversion $MDC_{95}$, Nm | 6.81 | 5.12 | 3.09 |

Abbreviations: ICC, *intraclass correlation coefficient; CI, confidence interval; SEM, standard error of the mean; MDC, minimal detectable change.* Descriptive data are presented as mean ± SD.

0°. In cases of acute ankle sprain, 7° of inversion would still be an acceptable position that would not stress the injured ligaments.

We also think there is an elastic component involved—during isometric muscle contraction there is an elastic deformation in the forefoot, which changes the actual angle of measurement. This deformation, even of a few degrees, has greater influence on eversion than on inversion, because in the natural ankle range of motion, eversion is smaller than inversion. Based on our results, to compensate for this elastic deformation, 7° of inversion is sufficient.

Based on this we suggest that the optimal testing position of the dynamometer footplate is 7° of inversion—it best represents both eversion and inversion and is a reliable method that can be used in clinical practice even in cases of acute ankle sprains.

Further research is planned to investigate isometric testing results' correlation with ankle-sprain symptoms such as pain, swelling, and so on.

To get more accurate results, more subjects could be included in the study. In further research, standardization of shoes for testing might be taken into consideration.

## Conclusions

Isometric calf-muscle strength testing using the Biodex 4 Pro System is a reliable method, and it can be used in clinical practice. We suggest that the angle of 7° of inversion is the best for isometric eversion and inversion testing.

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