Passive Resistive Torque of the Plantar Flexors Following Eccentric Loading as Assessed by Isokinetic Dynamometry

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Abstract/Résumé

Isokinetic dynamometers may provide a useful means of measuring muscle stiffness resulting from eccentric exercise because they can measure torque from computer-controlled passive movements of joints (passive resistive torque; PRT). In this study, a Biodex measured increased ankle PRT (52%; \( p < .001 \)) following heel drop exercise in nine young women. Therefore, isokinetic dynamometers can provide a means to study group changes as a result of eccentric exercise. Future studies are required to determine the reliability of this protocol before it can be advocated in studying single cases.

Il est possible d’utiliser les dynamomètres isokinétiques comme appareil de mesure de la rigidité élastique d’un muscle au cours d’une action pliométrique, car ils sont sensibles au moment de force produit par des mouvements passifs (moment de résistance passive, PRT) sous le contrôle d’un ordinateur. Dans cette étude, un appareil de marque Biodex enregistre chez neuf jeunes femmes une augmentation du PRT de la cheville (52 %; \( p < .001 \)) à la suite d’un exercice d’abaissement du talon. Par conséquent, on peut obtenir cette mesure chez un groupe d’individus ayant accompli cette action pliométrique. D’autres études devront établir la fiabilité d’une telle approche avant de l’appliquer à des études de cas.
Introduction

Unaccustomed eccentric (ECC) exercise typically results in delayed onset muscle soreness and decrements in muscle function (Clarkson and Sayers, 1999). One example of reduced muscle function is limited range of active and passive motion whereby subjects can lose a substantial amount of flexibility (Sayers et al., 2000). Typically the increased stiffness associated with eccentric exercise has been measured indirectly by measuring range of motion using a goniometer (Sayers et al., 2000). One problem with this type of measurement is that the end points of the range of motion are subjectively determined by either the subject or the investigator. In order to more objectively and directly measure stiffness of a muscle joint complex, custom built devices have been used (Chesworth et al., 1991). The disadvantage with this method is that most of the equipment is not readily available and is very specific to measuring only stiffness, and only stiffness of a specific joint.

Many isokinetic dynamometers now available and being used for strength or endurance testing, have the capabilities to measure muscle joint complex stiffness. For example, a passive mode can be used to measure the passive resistive torque of a specific muscle joint complex. Passive resistive torque is the resistance, measured in newton metres (Nm), that the dynamometer must overcome in order to move the joint through a specified range of motion. The greater the stiffness of the muscle joint complex, the greater the passive resistive torque will be, and the smaller range of motion that a person could actively move through. For example, older subjects who have increased passive resistive torque are unable to actively move through as large a range of motion as younger subjects (Porter et al., 1997).

The purpose of this study was to determine whether an isokinetic dynamometer can be used to measure changes in the passive resistive torque (PRT) of the plantar flexor muscle joint complex following ECC exercise. In this study subjects acted as their own controls with one leg performing heel drops, and both legs being tested for PRT. Heel drops were performed because they can provide eccentric contractions for the plantar flexor muscles (Svantesson et al., 1998), which are quantifiable, and most importantly because one leg alone can undergo the intervention. The hypothesis was that the Biodex System 2 isokinetic dynamometer would measure an increase in PRT in the experimental leg following the ECC exercise, whereas measures of the control leg would not change.

Methods

SUBJECTS

Ten female physical therapy students volunteered and gave their informed consent, according to the Lund University Department of Physiotherapy Ethics Committee. The nine subjects who completed the study were 24.8 ± 2.1 (mean ± SD) years old, weighed 66.9 ± 9.2 kg and were 169.2 ± 5.3 cm tall. On average they were involved in recreational physical activity 3.4 ± 0.6 days per week. One subject was excluded after the first session because she was unable to do the test passively.
Testing of PRT of the plantar flexors (PF) was followed immediately by the ECC loading exercise, heel drops. Twenty-four hours after the ECC loading exercise, PRT was tested again. Each subject acted as her own control, with only one leg undergoing the ECC loading exercise, but both legs being tested for PRT. Half the subjects were randomized to do the heel drops with the left leg and the other half with the right leg. The PRT testing of the legs (right vs. left) was alternated from pre to post to avoid order effects. Subjects were instructed to avoid recreational physical activity and stretching in the 24 hour period between test sessions.

**HEEL DROP EXERCISE**

Each subject performed heel drops at a rate of 56 bpm, with the down (ECC) phase including one count and the up (concentric) phase including a second count for a possible total of 28 heel drops per minute. The barefoot of the leg performing the heel drops (exercised leg) was positioned with the metatarsal heads on the edge of the bench, which was 24 cm high. Subjects were instructed to perform the heel drops such that they started with the heel above the level of the bench and dropped to below the level of the bench. The control leg was allowed to hang free. The subjects lightly rested their hands on a wall bar for balance support. Six sets were done, and the number of repetitions per set ranged from between 7 to 20 depending on subject fatigue or the ability to keep pace with the metronome. Thirty seconds of standing passive rest were given between sets. In total, subjects performed 57 to 87 drops in the six sets.

**PASSIVE RESISTIVE TORQUE TESTING**

Testing for passive resistive torque was performed with a Biodex System 2 isokinetic dynamometer (Biodex Medical Systems Inc., Shirley, NY). Subjects were positioned with their hips at approximately 80° (to minimize hamstring stiffness) and their knees at maximal extension. Stabilization straps were placed over the knee, foot and ankle. The ankle was moved passively by the Biodex itself through six continuous cycles between 10° plantar flexion to 10° dorsiflexion at 5°/s, with neutral (0°) being the line of the tibia perpendicular to the footplate. Gravity correction was done by the Biodex software. The subjects were instructed to stay relaxed and to view the Biodex monitor for feedback to ensure muscle inactivity. Visual analysis of the curves demonstrated consistent torque profiles, which indicated that the test was passive.

**DATA ANALYSIS**

The first cycle of the six passive cycles was discarded for all subjects, a priori, in order to allow for accommodation to the test. Torque at 10° of plantar flexion was subtracted from the torque at 10° dorsiflexion for each cycle to account for the baseline torque in the plantar flexed position, which was negligible. For each subject an average PRT was calculated from the five cycles. One investigator, who was blinded to the subject, test session, and control vs. exercised leg, performed all determinations of PRT in a random order. A repeated measures ANOVA was
performed; leg (control, exercised) and time (pre, post) being repeated factors, with a Bonferroni post hoc test, and \( p < 0.05 \) indicating a significant result.

**Results**

The repeated measures ANOVA resulted in significant effects for leg \( (p < 0.01) \) and time \( (p < 0.01) \), and an interaction which just missed significance \( (p = 0.054) \). The post hoc test showed that there was no significant difference in PRT between the control and exercised leg before the heel drop exercise \( (p = 0.7; \text{Figure 1}) \). The exercised leg significantly increased PRT by 52\% following the heel drop exercise \( (p < 0.001) \), while the control leg did not change significantly \( (p = 0.5) \), resulting in a higher PRT in the exercised leg at the post test \( (p < 0.001) \).

Because the control leg did not undergo the intervention, the reliability of the PRT test could be examined. The coefficient of variation (CV), which gives an indication of the reproducibility for the test, was fairly high at 24.5\% in this small group of subjects. Previous research has shown that PRT can be reliably measured on an isokinetic dynamometer in a standing position \( (CV = 11\%; \text{Porter et al., 1995}) \). Future research should be conducted with a larger group of subjects to determine the reliability and validity of PRT testing of the plantar flexors in a standard (seated) position on isokinetic dynamometers. In the case of this study the change seen in PRT as a result of ECC exercise was relatively large (52\%) compared to the measurement error (25\%), so PRT measured in this way was sufficiently effective.

![Figure 1](image-url)  
*Figure 1.* Comparison of the control and exercised legs. The eccentric exercised leg increased significantly \((^*p < 0.001)\) from pre to post.
Discussion

This study has demonstrated that increases in PRT as a result of ECC-biased exercise in a group of subjects can be measured with a commercially available dynamometer. A Biodex System 2 measured increased PRT of the plantar flexors 24 hours after heel drop exercise.

Being able to measure PRT in this way means that research into interventions to minimize muscle stiffness after ECC exercise can be evaluated. Interventions include exercise, therapy modalities such as ice or heat, as well as pharmacological aids. Dynamometer testing provides an objective measure that is not affected by subject or tester factors (Chesworth et al., 1991), like goniometer testing would be. For example, as was done in this study the tester can be blinded in performing the evaluation of test results, and the subject is not required to volitionally move which may be affected by pain sensations or other factors. Isokinetic dynamometers are available in many research facilities, but the capability to do this type of PRT testing is presently not used very often. PRT testing could become an additional feature of isokinetic dynamometers rather than only strength or endurance testing.

At this point, caution should be used in adopting this type of test for clinical or individual rather than group purposes because the method error was relatively high. In this study, though, the method error was lower than the effect of the eccentric exercise so the group change in PRT was able to outweigh the method error. It is unclear why the method error was so high in this study. Factors affecting reliability of a test such as this include: subject variability with time, tester experience and practice, the reliability of the equipment itself, and the actual protocol. In addition, with a small homogeneous sample one subject can have a large effect. Future research should examine the reliability of this type of test with a larger sample size, a broader range of subjects (i.e., varying physical activity backgrounds, men and different age groups), more familiarization for subjects, and with muscle groups other than the plantar flexors.

References