Eccentric/concentric ratios at selected velocities for the invertor and evertor muscles of the chronically unstable ankle

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Abstract

Objective—The use of muscle balancing by the clinician to determine return to activity or discharge of a patient is not a well understood measure. Because of the lack of information on the poorly understood concept of eccentric/concentric (E/C) ratios at the ankle, the purpose was to determine the E/C ratios for the invertor and evertor muscles at various velocities in healthy and chronically unstable ankles.

Methods—Ten subjects with healthy ankles and 14 with chronically unstable ankles performed five maximal effort reciprocal eccentric/contraction contractions on an isokinetic dynamometer at four velocities (60, 120, 180, and 240°/s) and for each physiological movement of inversion and eversion. Data were analyzed using a two-way mixed model analysis of variance with repeated measures, with Tukey’s test used for post hoc analysis.

Results—Although the chronically unstable ankle was significantly weaker (p<0.05) eccentrically and concentrically for inversion and eversion, the main effect of the E/C ratios for the ankle was not significant for either joint motion. The main effect of velocity was significant (p<0.05) for each joint motion, but no significant interaction effects were observed. As velocity increased, the E/C ratio increased, except at 180 and 240°/s for either ankle group.

Conclusions—Chronic ankle instability and muscle weakness co-exist. Adequate E/C ratios in the chronically unstable ankle may exist in the absence of normal strength values.


Keywords: isokinetics; strength ratios; ankle instability
Experimental design
A between ankle group (healthy × chronically unstable) repeated measures design was used. The repeated measures included joint motion (inversion, eversion), muscle contraction type (concentric, eccentric), and velocity (60, 120, 180, and 240°/s). The E/C ratios used in the analyses were determined from the dependent variable of mean peak torques (N.m). All tests were performed on each subject.

Methods
SUBJECTS
Table 1 gives the demographics of the subjects. The control group consisted of 10 subjects (five men, five women; mean (SD) age 26.0 (3.14) years) with no prior history of pathology to either lower extremity. The chronic instability group consisted of 14 subjects (seven men, seven women; mean (SD) age 26.6 (4.29) years) who had sustained at least two moderate sprains to the same ankle which required medical intervention and who complained of repeated episodes of “giving way”. No subjects in the chronic instability group had suffered injury to the unstable ankle for at least six months before testing, were undergoing rehabilitation of the ankle, or had any complaints of pain, swelling, or functional limitations. Active range of motion (dorsiflexion/plantarflexion; inversion/eversion) as measured using a standard goniometer were observed to be within normal limits (±2°) for both groups. No subject was involved in physical activity that exceeded three sessions a week for more than half an hour per session. Written consent was obtained from each subject before testing, and all subjects were screened to ensure that there were no lower extremity neuromuscular or musculoskeletal problems or contraindications for isokinetic testing.

PROTOCOL
Subjects performed a five minute warm up of general range of motion and stretching exercises for the joint movements of inversion/eversion and dorsiflexion/plantarflexion.

After the warm up, they were appropriately positioned on the isokinetic dynamometer (Henley Health Care Systems, Cybex Medical Division, Ronkonkoma, New York, USA) which was calibrated before testing each subject. The ankle joint was positioned in neutral of inversion, and eversion was identified using palpation during passive movements of the talus. The knee of the test leg was positioned in 80–110° flexion and the lower leg was parallel to the floor. The ankle joint was positioned in 10–15° plantarflexion as a consequence of the low cut lace up shoe worn by each subject that simulated a position for inversion injury. Two straps crisscrossing the dorsum of the foot held it against the footplate. The thigh stabiliser pad and strap secured the distal aspect of the thigh for the test leg and a seatbelt placed around the abdomen secured the torso.

Four submaximal (50% effort) trials were followed by five maximal effort concentric/eccentric reciprocal contractions at each velocity (60, 120, 180, and 240°/s) and for each physiological movement (inversion, eversion). To ensure that maximal effort was being attained, a cursory review of the five maximal effort torques was performed to verify that all efforts were within 0.5 N.m of the peak torque. A two minute rest was permitted between the test for inversion and eversion joint motions to prevent fatigue build up.

DATA ANALYSIS
Two way (ankle group × velocity) mixed model analyses of variance with repeated measures of the E/C ratios were used separately for joint movements of inversion/eversion and dorsiflexion/plantarflexion.
Chronic ankle instability

Eversion
Group inversion

Healthy 1.40 (0.21) 1.72 (0.29) 1.96 (0.23) 2.19 (0.36)
Chronic 1.45 (0.24) 1.83 (0.57) 2.00 (0.62) 2.20 (0.74)

Discussion
Traditionally, clinicians have used comparisons of the strength values between similar muscle groups on opposite extremities or considered the muscle antagonistic ratios to determine if a patient is rehabilitated. Although technological advances have led to the use of isokinetics to improve evaluation, isokinetic assessment has often been limited to concentric muscle contraction types. However, we can now expand these measures to include eccentric contractions and focus on the contraction mode dependent order of muscle strength which gives rise to the E/C ratio. It has been substantiated that abnormalities in the E/C ratio may imply pathology or predispose to injury.

Muscle weakness and chronic instability at the ankle were found to co-exist. The chronically unstable ankle was significantly weaker than the healthy ankle regardless of muscle contraction type or joint motion. While this observed relation between peroneal muscle weakness and chronic instability supported earlier findings, a similar finding was also observed for the invertor muscles which is a new finding. The chronically unstable ankle would appear to be at risk of reinjury.

Subject demographics have often been considered to be a factor in the production of strength output. In this study, the variables of age and height were similar between the groups with healthy and chronically unstable ankles. While there was some variability in weight between the two groups, the differences are not considered to be an issue in the results observed. According to Perrin, demographic variables are thought to be a factor in the production of strength in the larger joints of the body. However, the ankle is considered to be a small joint and when tested in a gravity-free position is not affected as such.

The eccentric peak torques for the evertor muscles produced for either ankle group were observed to decrease at the higher velocities of 180 and 240°/s, contrary to the established force-velocity relation. Maximal eccentric contractions may have been diminished by the consecutive eccentric/concentric testing because eccentric contractions are more fatiguing than concentric contractions and the differences are more pronounced at velocities over 150°/s. Although the decrements were not statistically significant, clinically they suggest an inability of the evertor muscles to work eccentrically at the faster velocities, which are considered to be more functionally representative of activities of daily living. Ligamentous injury typically occurs when the peroneal muscles are called upon to work eccentrically in response to high velocity movements. However, at the higher velocity of 240°/s which is functionally relevant, the ability of the evertor muscles to work eccentrically was reduced, causing functional muscle activity around the ankle to be impaired under eccentric and high velocity conditions.

This study supports the idea of a contraction mode dependent order of muscle strength and the magnitude of the moments generated in both contraction modes being velocity dependent. The E/C ratios for the joint motions were found to be similar in the two ankle groups and to increase proportionately with increasing velocities, which supports previous research on healthy subjects tested at the elbow and knee. As a consequence, our hypothesis was rejected.

Opinions on acceptable E/C ratios are diverse. In a summary by Dvir, it was reported that E/C ratios (derived from low to medium test velocities for healthy subjects) using single
joint testing such as the knee and shoulder should be within a range of 0.95–2.05. Table 3 provides an E/C ratio summary along with the results for the healthy subjects in the present study. If the velocity of 240°/s is excluded, the E/C ratios for the healthy subjects are within acceptable limits.12

For the chronically unstable ankle, the mean E/C ratios for inversion and eversion joint motions were 1.55 (range 0.80–2.20) and 1.87 (range 1.09–3.67) respectively. The variability observed for the chronically unstable ankle is greater than for the healthy ankle, suggesting inappropriate muscle strength, particularly for the evertor muscles. As the E/C ratio increases, either the eccentric force has increased compared with the concentric force or the concentric torque has decreased compared with the eccentric torque. If one reconsiders the force-velocity relation, the ability of the evertor muscles in the chronically unstable ankle to maintain concentric torque production as velocity increased was inadequate compared with the invertors. These findings may help to explain the high incidence of chronic instability and the susceptibility of the healthy ankle to injury.15 21 Rehabilitation should include not only concentric muscle strengthening but eccentric muscle strengthening, particularly for the evertors. These findings may help to explain the high incidence of chronic instability and the susceptibility of the healthy ankle to injury.15 21 Rehabilitation should include not only concentric muscle strengthening but eccentric muscle strengthening, particularly for the evertors. Previous studies have shown that the ankle is particularly susceptible to injury in the chronic ankle sprain.15 21

Table 3 | Range of E/C ratios in the literature

<table>
<thead>
<tr>
<th>Reference</th>
<th>Joint</th>
<th>Range</th>
<th>Velocity (°/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kramer and MacDermid7</td>
<td>Knee</td>
<td>1.1–1.5</td>
<td>45–180</td>
</tr>
<tr>
<td>Rizzardo et al8</td>
<td>Knee</td>
<td>1.3–1.7</td>
<td>60–180</td>
</tr>
<tr>
<td>Collander and Tesch1</td>
<td>Knee</td>
<td>1.2–1.6</td>
<td>30–150</td>
</tr>
<tr>
<td>Griffin1</td>
<td>Elbow</td>
<td>1.1–1.3</td>
<td>30–120</td>
</tr>
<tr>
<td>Horrobagyi and Katch1</td>
<td>Elbow</td>
<td>1.4–1.7</td>
<td>30–120</td>
</tr>
<tr>
<td>Dvir1</td>
<td>Shoulder (IR)</td>
<td>1.1–1.2</td>
<td>60–180</td>
</tr>
<tr>
<td></td>
<td>Shoulder (ER)</td>
<td>1.2–1.7</td>
<td>60–180</td>
</tr>
<tr>
<td></td>
<td>Ankle (Inv)</td>
<td>1.05–2.00</td>
<td>60–240</td>
</tr>
<tr>
<td></td>
<td>Ankle (Eve)</td>
<td>1.17–2.83</td>
<td>60–240</td>
</tr>
</tbody>
</table>

Eccentric and concentric contraction types. Although joint movements during the activities of daily living may exceed this velocity, the information gained on peak torques and E/C ratios should still be valuable to the clinician in determining deficits.12

CLINICAL RELEVANCE
Chronic instability and muscle weakness co-exist at the ankle and are particularly evident at the higher more functionally relevant velocities. The E/C ratios for the chronically unstable ankle are not significantly different from those for the healthy ankle. Although appropriate balancing of muscle contraction types, as determined by the E/C ratios, may exist in the chronically unstable ankle, the clinician should be aware of this existence in the absence of normal strength values when considering a return to activity for the patient.