Measuring Lower Extremity Strength in Older Adults: The Stability of Isokinetic Versus 1RM Measures

George J. Salem, Man-Ying Wang, and Susan Sigward

In order to obtain joint-specific baseline strength characteristics in older adults, clinicians and researchers must have knowledge regarding the relative stability of the various strength tests (the strength difference between repeated measures) and the number of prebaseline practice sessions required to obtain consistent data. To address these needs, the relative multiple-test stability and reliability associated with lower extremity isokinetic and 1-repetition-maximum (1RM) strength measures were assessed in a sample of older adults (N = 30, 65.2 ± 6.3 years), over 4 weeks (T1–T4). Isokinetic ankle plantar-flexion (30°/s) strength and 1RM ankle plantar-flexion, leg-press, and knee-flexion strength exhibited poor stability between Weeks T1 and T2 but stabilized between Weeks T2 and T3 and Weeks T3 and T4. The measures exhibited low incidence of injury and induced low levels of residual muscle soreness. Findings suggest that the 1RM measures require at least 1 prebaseline training session in order to establish consistent baseline performance and are more reliable than isokinetic ankle plantar-flexion tests.

Key Words: one-repetition maximum, elders, resistance

The assessment of muscle strength in older adults is an increasingly important element in understanding age-related functional-performance declines, prescribing therapeutic exercise, and quantifying intervention outcomes in controlled-trial studies. Clinicians and researchers have used isometric and isokinetic dynamometry, one-repetition- and multiple-repetition-maximum lifts, and functional-assessment measures to quantify physical performance and adaptation in elders. Many older participants, however, are unfamiliar with these testing procedures; thus, the stability, participant acclimation, and safety associated with these relatively “novel” test instruments are of concern. Moreover, information regarding the number of prebaseline practice sessions that should be performed before one can collect reliable performance data using these methods is essential yet rarely addressed (Frontera, Hughes, Dallal, & Evans, 1993).

The importance of participant familiarization with strength-assessment protocols is evidenced by the statistically significant increases in strength that have

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been reported after repeat measurements without intervention in older adults (Frontera et al., 1993; Harries & Bassey, 1990). Strength increases in these studies are likely the result of motor-learning adaptations, because muscle morphological changes are minimal during the early phase of resistance training (Enoka, 1988; Hakkinen, Pakarininen, & Kallinen, 1992; Jones, Rutherford, & Parker, 1989). Reports of single test–retest repeatability of lower extremity isokinetic strength measures in older adults are varied and contradictory (Frontera et al., 1993; Harries & Bassey; Morris-Chatta, Buchner, de Lateur, Cress, & Wagner, 1994; Murray, Duthie, Gambert, Sepic, & Mollinger, 1985); moreover, there are no reports of the multiple-test stability of isokinetic measures of peak strength in elders. Repetition-maximum testing, including one-repetition-maximum (1RM) testing, has also been used to assess muscle strength in elders (Atha, 1981; Fiatarone et al., 1990; Frontera, Meredith, O’Reilly, Knutgen, & Evans, 1988; Judge, Underwood, & Gennosa, 1993; Nichols, Omizo, Peterson, & Nelson, 1993). Reports suggest that 1RM assessments can be employed safely in older adults (Barnard, Adams, Swank, Mann, & Denny, 1999; Di Fabio, 2001), but the multiple-test stability of these tests in older adults is also questionable.

Although these previous reports might inform clinicians and researchers regarding the repeatability of strength measurements in older adults performed over two separate measurement periods during a relatively short time period (typically 7–14 days), they do not provide information regarding the multiple-test stability (i.e., the strength difference between repeated measures) of these maximum-effort tests or the comparative stability of 1RM and isokinetic measures. This type of comparative information, however, could inform clinicians and researchers in their selection of the most appropriate strength measures to use (e.g., those exhibiting the greatest stability) and the number of prebaseline practice sessions required to obtain consistent baseline strength data.

The purpose of this investigation was to characterize the comparative multiple-test stability, repeatability, and muscle-mass changes associated with lower extremity isokinetic and 1RM strength measures in a single sample of older adults over four weekly test periods. Multiple-test stability was assessed by examining the differences in the mean values of the measures among four tests. Repeatability was assessed by examining the average coefficients of variation and reliability coefficients associated with the first two test sessions and the last two test sessions, for each measure. Injury incidence and associated muscle soreness were assessed to provide information regarding the safety of these maximum-effort tests in older adults, whereas midthigh lean and fat mass were measured to determine whether changes in strength performance were the result of muscle-mass changes or participant familiarization with the testing procedures.

### Methods

#### DESIGN

Experimental procedures were conducted at the Musculoskeletal Biomechanics Research Laboratory and the Exercise Physiology Laboratory at the University of Southern California’s Department of Biokinesiology and Physical Therapy. The University of Southern California’s Institutional Review Board approved the
research protocol, and all participants consented to participate after being informed of the procedures. Participants performed tests of muscle strength (isokinetic and 1RM) once weekly for 4 weeks. A single research associate performed all test procedures, and the sequence of the tests was randomized. All testing procedures were performed in the morning to limit the potential influence of fatigue.

PARTICIPANTS

Participants were recruited from the greater Los Angeles metropolitan area. Medical-history forms and a physician’s “permission to participate” letter were reviewed to obtain inclusion/exclusion information. A total of 32 healthy older adults (7 men and 25 women, 51–78 years old), having no previous isokinetic dynamometry-testing or weight-lifting experience, were selected to participate in the study. The sample size was determined from a power analysis ($p < .05$, $1 - \beta = .8$) of previously reported older adult strength data collected in our laboratory (Greendale et al., 2000). All participants were free from current musculoskeletal injury and cardiovascular disease and were required to maintain their physical activity level throughout the study.

STRENGTH-TESTING PROCEDURES

Bilateral knee-extension, knee-flexion, ankle plantar-flexion, and leg-press strength were assessed using a 1RM procedure and standard plate-loaded resistance-exercise equipment. Participants performed one warm-up set of three submaximal repetitions for each test measure. They then performed a series of single-repetition, maximum-effort sets with progressively increasing resistance. For the baseline visit, the resistance was initially increased in increments of 10 kg for the first three sets and then in 1- to 2-kg increments for the remaining one-repetition sets. The tests were stopped when the participant could no longer “lift” the resistance through a full range of motion. The participant’s 1RM was recorded as the last resistance lifted before the failed attempt. An average of six attempts were required to obtain the participant’s 1RM during the first test session. During Sessions 2–4, the investigator typically determined the participant’s 1RM within three attempts.

Ankle plantar-flexion 1RM testing was performed on a “calf-strengthening” machine (Body-Solid, Inc., Forest Park, IL) with the participant seated at a knee angle of 90° (Figure 1). The joint angle was selected to match the knee position used during the isokinetic measurements. The participants then performed a heel-raise maneuver through a full range of motion.

Knee-extension and -flexion 1RM tests were performed on a combination “knee-strengthening” machine (Body-Solid, Inc.). Consistent with the isokinetic testing, the participants sat upright at a hip-flexion angle of 90°. The crossbar was positioned 2 finger widths above the malleoli. Resistance weights were added to the crossbar at each set until the participant could no longer extend the leg from 90° of knee flexion to full extension (knee-extension test) and flex the leg from full knee extension to 90° of flexion (knee-flexion test).

Leg-press 1RM testing was performed on a seated leg-press machine (Hammer Strength, Franklin Park, IL). The participants were positioned at approximately 90° of knee and hip flexion and were required to push against the platform through
full knee extension. The testing position for each participant was recorded at the baseline measurement and was used throughout the duration of the study.

Isokinetic-strength measures consisted of maximum-effort isokinetic knee-extension, knee-flexion, and ankle plantar-flexion torques of the dominant limb, which were measured using the Kin-Com 500H (Chattecx, Hixon, TN) isokinetic dynamometer. The Kin-Com setup and participant positioning were in accordance with the standardized testing procedures provided by the manufacturer. For the knee, isokinetic concentric extension and flexion muscle tests were conducted at angular velocities (60 and 120°/s) that are commonly used to assess knee-strength adaptations in older adults (Brown & Holloszy, 1991; Frontera et al., 1988; Laforest, St-Pierre, Cyr, & Gayton, 1990). The participants were positioned against a back support with a hip angle of 90°, and knee-joint range of motion (measured posteriorly) was set between 100° and 160°. For the ankle, isokinetic concentric plantar-flexion strength was measured at speeds of 30 and 60°/s with a testing range of motion between 5° of dorsiflexion and 20° of plantar flexion. These velocities are also used to examine ankle strength in older adults (Brown & Holloszy; Danneskiold-Samsoe et al., 1984; Judge, Davis, & Ounpuu, 1996; Thelen, Ashton-Miller,
The participants were seated with the knee positioned at 90°. Leg support was provided at the distal third of the thigh, and stabilizing belts were secured over the lap, forefoot, and tibia/fibula just superior to the malleoli (Figure 2). The test positions for each participant were recorded at baseline and used during the three subsequent weekly testing periods; thus, a consistent moment-arm length for each participant was used throughout the study.

Before each isokinetic test, participants were asked to perform one submaximal and one maximal contraction for practice. During testing, three separate single-repetition trials were performed. The maximum peak torque produced over the three trials was used for analysis. Peak torque is routinely referenced as the absolute strength of an individual and is used extensively in studies assessing strength in older adults (Brown & Holloszy, 1991; Danneskiold-Samsoe et al., 1984; Frontera et al., 1988; Judge et al., 1993; Laforest et al., 1990; Reuben & Siu, 1990).

PARTICIPANT INSTRUCTIONS

All participants were told that the study was being conducted in order to determine which strength measures were “most repeatable” and therefore “most appropriate” for use in future older adult exercise studies. The participants clearly understood...
that they were not participating in an “intervention” study. During each laboratory visit over the 4-week period and before testing the participants were reminded to provide a maximal effort and encouraged to push or pull “as hard and as fast as they can during all tests.” No visual feedback was provided during either the isokinetic or the 1RM test; however, participants could see their joint positions during the knee-extension, ankle plantar-flexion, and leg-press 1RM tasks. During performance of the maximum-effort tests, the research associate provided standard verbal prompts.

LEAN- AND FAT-MASS CHANGES

In order to determine whether the multiple strength-testing procedures altered the participants’ midheight-segment lean mass and fat mass, dual-energy X-ray absorptiometry (DXA) scans (Hologic QDR-1500 software, version 7.1, Waltham, MA) were performed at baseline and at 4 weeks. Using the slice-analysis mode for the whole-body DXA scan, site-specific measurements of lean and fat mass were performed at the junction of the proximal and middle third of the femur (Hawkins et al., 1999). A single, experienced research associate performed and analyzed all scans. The coefficient of variation (CV) for repeated measures using this method in our laboratory is less than 1%.

MUSCLE-SORENESS AND INJURY ASSESSMENT

Participants used a standardized questionnaire, developed specifically for the study, to report any injuries or muscle soreness the week after each test period. Those reporting soreness also rated their perception of pain on a perceived-pain scale (1 = no pain, 10 = severe pain).

Statistical Analysis

One-way, repeated-measure ANOVAs were used to identify differences in the mean values of each strength measure among the four repeated test sessions. The assumption of sphericity of the repeated-measure ANOVAs was assessed using Mauchly’s test of sphericity (Mauchly, 1940). Significance levels were adjusted whenever the sphericity assumption was violated, using a Huynh-Feldt adjustment. If a statistically significant ($p \leq .05$) main effect was identified, post hoc paired t-tests were used to identify statistically significant differences in the mean values between sessions T1 and T2, T2 and T3, and T3 and T4. The $p$ values were adjusted for the multiple post hoc comparisons using a Bonferroni correction. CVs between the first two test sessions (T1 and T2) and the last two test sessions (T3 and T4) were calculated for each participant and averaged across all participants. Reliability coefficients (Cronbach’s alpha) were also calculated between the first two test sessions (T1 and T2), the last two test sessions (T3 and T4), and across all test sessions (T1–T4). One-way, repeated-measure ANOVAs were used to identify differences in the mean values of midheight-segment lean mass and fat mass between the T1 and T4 measurements. All statistical analyses were performed using SPSS version 9.0 statistical-analysis software (SPSS, Chicago, IL).
Results

MUSCLE SORENESS AND INJURY

Thirteen of the 32 participants reported muscle soreness in their legs or lower back after their first test session. The average perceived pain among participants reporting residual pain was 2.3/10. One female participant aggravated a previous lower back injury after her baseline test session and elected to not participate further in the study. Nine, 6, and 7 of the remaining 31 participants reported residual pain after their second, third, and fourth visits, respectively. The range of reported perceived pain was between 2.0 and 2.4 for these test sessions. One male participant experienced muscle cramping during the third test session and had continued discomfort at the fourth test session. Because the cramping might have influenced his performance, his data were excluded from all further analyses. Thus, data from a total of 30 participants (24 women and 6 men) with an average age of 65.2 ± 6.3 years were used for the comparative analyses.

GENDER EFFECT

Averaged across all measures, CVs between male and female participants were not appreciably different (7.6% ± 2.7% and 6.8% ± 4.2%, respectively); thus, data for both genders were pooled.

STABILITY

The ANOVA analysis identified a statistically significant difference among the mean values of the repeated isokinetic ankle plantar-flexion torque tests at 30°/s ($F = 4.509, df = 3.0, p = .005$). Peak ankle plantar-flexion torque at 30°/s increased between test sessions T1 and T2 ($t = 2.87, p = .057$; Table 1). No other isokinetic measure changed statistically significantly between test sessions. ANOVA analyses identified statistically significant differences among the mean values of the repeated 1RM ankle plantar-flexion ($F = 5.789, df = 2.153, p = .004$), leg-press ($F = 15.909, df = 2.464, p < .001$), and knee-flexion ($F = 6.076, df = 2.586, p = .002$) tests. There were statistically significant increases in 1RM ankle plantar-flexion ($t = 2.869, df = 29, p = .024$), leg-press ($t = 5.418, df = 29, p < .001$), and knee-flexion ($t = 3.015, df = 29, p = .015$) loads between test sessions T1 and T2 (Table 2). All 1RM measures stabilized after session T2, and no other between-session 1RM differences were identified.

RELIABILITY

Reliability coefficients were high for the isokinetic knee-extension and -flexion tests and the 1RM tests, ranging from .87 to .97 among the T1–T2, T3–T4, and T1–T4 test sessions (Table 3). The reliability coefficients for ankle plantar flexion at 30 and 60°/s ranged from .73 to .81. The CVs for the isokinetic knee-extension and -flexion tests were all below 6.7%, whereas the CVs for the isokinetic ankle plantar-flexion tests were between 12.8% and 13.5% (Figure 3). The CVs for all 1RM between-session comparisons were between 4.4% and 8.5%.
Table 1 Isokinetic Peak Torque

<table>
<thead>
<tr>
<th></th>
<th>Test 1 ($M \pm SD$)</th>
<th>Test 2 ($M \pm SD$)</th>
<th>$% \Delta_1$</th>
<th>Test 3 ($M \pm SD$)</th>
<th>Test 4 ($M \pm SD$)</th>
<th>$% \Delta_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>KE 60 (Nm)</td>
<td>93.2 ± 32.2</td>
<td>92.9 ± 30.1</td>
<td>−0.3</td>
<td>93.5 ± 32.3</td>
<td>92.4 ± 33.2</td>
<td>−1.2</td>
</tr>
<tr>
<td>KE 120 (Nm)</td>
<td>71.2 ± 24.5</td>
<td>72.1 ± 23.9</td>
<td>1.3</td>
<td>70.0 ± 25.4</td>
<td>69.9 ± 27.0</td>
<td>−0.1</td>
</tr>
<tr>
<td>KF 60 (Nm)</td>
<td>59.7 ± 21.6</td>
<td>60.5 ± 21.2</td>
<td>1.3</td>
<td>60.6 ± 22.3</td>
<td>60.1 ± 23.4</td>
<td>−0.8</td>
</tr>
<tr>
<td>KF 120 (Nm)</td>
<td>54.7 ± 20.4</td>
<td>54.8 ± 19.9</td>
<td>0.2</td>
<td>55.4 ± 19.8</td>
<td>55.5 ± 21.3</td>
<td>0.2</td>
</tr>
<tr>
<td>APF 60 (Nm)</td>
<td>12.5 ± 4.0</td>
<td>12.3 ± 4.1</td>
<td>−1.6</td>
<td>13.1 ± 5.1</td>
<td>12.3 ± 4.1</td>
<td>−6.1</td>
</tr>
<tr>
<td>APF 30 (Nm)</td>
<td>14.8 ± 5.8</td>
<td>16.3 ± 5.6</td>
<td>10.1a</td>
<td>17.3 ± 6.2</td>
<td>15.8 ± 5.5</td>
<td>−8.7</td>
</tr>
</tbody>
</table>

Note. $\% \Delta_1 =$ percent change between Test 1 and Test 2; $\% \Delta_2 =$ percent change between Test 3 and Test 4; KE 60 = knee-extension peak torque at 60°/s; KE 120 = knee-extension peak torque at 120°/s; KF 60 = knee-flexion peak torque at 60°/s; KF 120 = knee-flexion peak torque at 120°/s; APF 60 = ankle plantar-flexion peak torque at 60°/s; APF 30 = ankle plantar-flexion peak torque at 30°/s.

aAdjusted $p = .057$ for post hoc paired $t$ test where the peak torques differed between measurement sessions ($p$ values were adjusted for the multiple comparisons using a Bonferroni correction).
### Table 2 One-Repetition-Maximum Loads

<table>
<thead>
<tr>
<th></th>
<th>Test 1 (M ± SD)</th>
<th>Test 2 (M ± SD)</th>
<th>%Δ₁</th>
<th>Test 3 (M ± SD)</th>
<th>Test 4 (M ± SD)</th>
<th>%Δ₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle plantar flexion (kg)</td>
<td>48.9 ± 18.1</td>
<td>51.9 ± 17.8</td>
<td>6.2⁺</td>
<td>53.4 ± 19.0</td>
<td>54.9 ± 18.7</td>
<td>2.9</td>
</tr>
<tr>
<td>Leg press (kg)</td>
<td>92.3 ± 32.0</td>
<td>101.4 ± 32.7</td>
<td>9.9⁺</td>
<td>102.2 ± 33.5</td>
<td>104.6 ± 30.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Knee extension (kg)</td>
<td>30.8 ± 12.9</td>
<td>29.9 ± 12.4</td>
<td>−2.9</td>
<td>30.2 ± 11.0</td>
<td>30.2 ± 11.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Knee flexion (kg)</td>
<td>32.6 ± 12.4</td>
<td>35.3 ± 12.7</td>
<td>8.4⁺</td>
<td>37.0 ± 13.7</td>
<td>36.5 ± 14.2</td>
<td>−1.3</td>
</tr>
</tbody>
</table>

*Note. %Δ₁ = percent change between Test 1 and Test 2; %Δ₂ = percent change between Test 3 and Test 4.

⁺Adjusted p ≤ .05 for post hoc paired t test where the peak torques differed between measurement sessions (p values were adjusted for the multiple comparisons using a Bonferroni correction).
Table 3  Between-Session Reliability Coefficients (Cronbach’s alpha) for Isokinetic Peak Torque and One-Repetition-Maximum Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Test 1 to Test 2</th>
<th>Test 3 to Test 4</th>
<th>Test 1 to Test 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>KE 60</td>
<td>.976</td>
<td>.979</td>
<td>.982</td>
</tr>
<tr>
<td>KE 120</td>
<td>.973</td>
<td>.978</td>
<td>.987</td>
</tr>
<tr>
<td>KF 60</td>
<td>.979</td>
<td>.972</td>
<td>.987</td>
</tr>
<tr>
<td>KF 120</td>
<td>.969</td>
<td>.968</td>
<td>.982</td>
</tr>
<tr>
<td>APF 60</td>
<td>.839</td>
<td>.902</td>
<td>.930</td>
</tr>
<tr>
<td>APF 30</td>
<td>.899</td>
<td>.889</td>
<td>.932</td>
</tr>
<tr>
<td>1RM ankle plantar flexion</td>
<td>.973</td>
<td>.979</td>
<td>.978</td>
</tr>
<tr>
<td>1RM leg press</td>
<td>.979</td>
<td>.982</td>
<td>.978</td>
</tr>
<tr>
<td>1RM knee extension</td>
<td>.975</td>
<td>.975</td>
<td>.970</td>
</tr>
<tr>
<td>1RM knee flexion</td>
<td>.960</td>
<td>.956</td>
<td>.970</td>
</tr>
</tbody>
</table>

Note. KE 60 = knee-extension peak torque at 60°/s; KE 120 = knee-extension peak torque at 120°/s; KF 60 = knee-flexion peak torque at 60°/s; KF 120 = knee-flexion peak torque at 120°/s; APF 60 = ankle plantar-flexion peak torque at 60°/s; APF 30 = ankle plantar-flexion peak torque at 30°/s.

![Figure 3](image_url)  
Figure 3. Between-session coefficients of variation for isokinetic measures of peak strength (torque) and the one-repetition-maximum plantar-flexion test.
MIDTHIGH-SEGMENT MASS

There were no statistically significant differences in lean- or fat-mass composition between test sessions T1 and T4 (Table 4).

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T4</th>
<th>%Δ</th>
<th>alpha</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat (g)</td>
<td>199.4 ± 94.3</td>
<td>197.2 ± 95.9</td>
<td>−1.1</td>
<td>.998</td>
<td>2.46%</td>
</tr>
<tr>
<td>Lean (g)</td>
<td>367.0 ± 86.6</td>
<td>370.3 ± 91.3</td>
<td>0.9</td>
<td>.993</td>
<td>2.07%</td>
</tr>
</tbody>
</table>

Note. %Δ = percent change between T1 (Week 1) and T4 (Week 4); CV = coefficient of variation.

Discussion

This investigation examined the stability of isokinetic and 1RM strength measures in a sample of older adults over a 4-week period. Our findings suggest that caution be used when selecting and assessing measures of strength in older adults; for some tests, statistically significant differences in performance can be expected between weekly test sessions without intervention. Performance improvements were found between initial and follow-up test sessions, 1 week apart, for the isokinetic ankle plantar-flexion test (30°/s) and the 1RM ankle plantar-flexion, leg-press, and knee-flexion tests. We attribute these improvements in performance to an increased familiarity with the testing procedures rather than to training-induced increases in muscle protein, because the lean and fat mass of the thigh did not change over the testing period, and previous reports suggest that muscle morphological changes are minimal during the early phase of resistance training (Enoka, 1988; Hakkinen et al., 1992; Jones et al., 1989).

Statistically significant gains after repeated strength measurements without intervention in older adults have also been reported by Frontera and colleagues (1993), who identified increases of 5–20% in isokinetic knee-extensor/-flexor strength (60 and 240°/s) in 178 noninstitutionalized healthy men and women over a period of 7–10 days. Harries and Bassey (1990) reported that mean isokinetic concentric knee-extensor torque at 100°/s increased by 5% with repeated measurements 2 weeks apart; however, knee-extensor torques at higher angular velocities did not change. In contrast to these previous reports, Morris-Chatta and colleagues (1994) reported no statistically significant changes in older adult isokinetic ankle plantar-flexion strength in test–retest measurements taken 2–7 days apart. Their analysis methodology, however, which included multiple testers, makes it difficult
to compare their results with those of the present study. Morganti and colleagues (1995) reported non-statistically significant changes in 1RM leg-press and 1RM knee-extension strength after repeated measures 1 week apart in women 59.5 ± 0.9 years of age. Their report is in agreement with our findings for the 1RM knee-extension measure but differs from our finding of a statistically significant increase in 1RM leg-press strength between T1 and T2 measurements. These disparate findings could potentially be attributed to differences in the type of resistance-exercise equipment used in the two studies.

All strength measurements stabilized after the second test, and statistically significant differences between T2 and T3 and T3 and T4 were not found. These findings affirm that in regard to the 1RM ankle plantar-flexion, leg-press, and knee-flexion measures and the isokinetic ankle plantar-flexion test at 30°/s, prebaseline maximum-effort practice sessions are needed to determine consistent baseline strength characteristics for older adults during clinical treatments and controlled-trial research designs. Encouragingly, however, these data also suggest that a single maximum-effort practice session, performed 1 week earlier, should be sufficient to prepare participants to consistently reproduce their maximum-effort performance.

Between test sessions T1 and T2, the least reliable measures were the isokinetic concentric ankle plantar-flexion tests. These measures had CVs 91–155% greater than those of the other isokinetic measures and 98–110% greater than the 1RM ankle plantar-flexion test. Furthermore, the relatively large isokinetic plantar-flexion CVs changed little between test sessions T1 and T2 and test sessions T3 and T4, suggesting that our older participants did not acclimate to these isokinetic-testing procedures. The reliability data (reported alphas) are consistent with this interpretation. Fiatarone and colleagues (1990) reported that the CV associated with their 1RM knee-extension protocol was 13% in participants 90 ± 1 years of age. Our reported CVs for the 1RM measures were all below 9%; however, we used a younger participant sample. Others have reported excellent repeatability for older adults in 1RM tests of the upper extremity (Laidlaw, Kornatz, Keen, Suzuki, & Enoka, 1999) and in lower extremity 1RM tests using pneumatic resistance-exercise equipment (Tracy et al., 1999).

Clinicians and researchers can use information from this investigation to select the most appropriate lower extremity strength measures for older adults. In regard to the ankle plantar-flexion tests, the relatively low CVs and high reliability coefficients associated with the 1RM measure lead us to recommend this test over the isokinetic tests when assessing peak strength. Nevertheless, our stability results affirm the need to practice the 1RM ankle plantar-flexion tests during prebaseline practice sessions in order to determine repeatable baseline performance levels. In contrast to the measures of ankle plantar-flexion strength, the high stability, low CVs, and high reliability associated with all knee-flexion and -extension measures reported render it impossible to determine a superior knee-strength measure based solely on these characteristics. Consequently, we believe the selection of appropriate knee-flexion and -extension strength measures should be based on principles of exercise specificity and therefore should use testing procedures and protocols that are most similar to the exercises used in the clinic or performed during intervention studies. For example, isokinetic tests of knee strength are likely to be most ap-
appropriate if the older adult participants are training on an isokinetic resistance machine. Conversely, a 1RM test might be more appropriate if the participants are using plate-loaded resistance-exercise equipment.

Previous exercise-intervention studies with older adults support this concept of “exercise specificity.” For example, Frontera and colleagues (1988) reported that older adults participating in a 12-week lower extremity exercise program using a resistance of 80% of their 1RM had an increased 1RM performance that was 10 times greater than their increased isokinetic (60°/s) performance. Brown, McCartney, and Sale (1990) found comparable results with a program isolating the elbow flexors of one arm. Although 1RM strength increased 48%, isokinetic strength increased only 8.8% and isometric strength did not change.

Interpretation of the results of this study should be made with an appreciation of the study’s limitations. The participants were a relatively homogeneous group of high-functioning ambulatory senior volunteers. Consequently, the extrapolation of these results to master athletes or physically frail elders is not recommended. The study only examined the reliability of isokinetic and 1RM measures of strength and did not examine additional measures of muscle performance such as muscle endurance, muscle power, or multiple-repetition-maximum strength. Although statistical-power considerations prevented the inclusion of these additional analyses, future investigations should also characterize these measures of muscle performance. Not addressed in the current investigation is the stability of these measures over longer time periods (e.g., 6 months). This information could be critical in study designs where pre- and poststudy strength measurements are several months apart. Consequently, we believe longer term assessments of stability in these measures are warranted. Finally, our study reports the incidence of injury for both lower extremity 1RM testing and maximum isokinetic testing. The study design, comparing measures of strength in a single sample, required that the participants perform both types of exercise during the same laboratory visits; thus, it was impossible to parcel out the effects of each of the exercises on participant muscle soreness and injury. Nevertheless, the relatively small incidence and severity of injury associated with these maximum-effort performances suggest that older adult participants can perform both types of tests safely.

When assessing the effectiveness of older adult rehabilitation programs and intervention trials, clinicians and researchers must decide whether the changes in physical performance reflect physiological adaptations or are merely artifacts of the testing procedures. Knowledge of the relative stability, reliability, and injury incidence of maximum-effort strength measures in older adults can be used by researchers and clinicians to develop appropriate practice and testing protocols to accurately measure strength adaptation. Our findings suggest that, with the exception of the isokinetic ankle plantar-flexion tests, lower extremity isokinetic and 1RM peak-strength measures are stable and exhibit low CVs and high reliability. Nevertheless, the statistically significant T1–T2 improvements identified with the 1RM ankle plantar-flexion, leg-press, and knee-flexion tests suggest that these measures should be practiced (perhaps with a 7-day follow-up) before establishing baseline values. In addition, when assessing peak ankle plantar-flexion strength, we recommend the 1RM measure over the 30 or 60°/s isokinetic measures because of the 1RM measure’s lower average CVs and higher reliability.
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References


