Intertrial Reliability of Work Measurements Recorded During Concentric Isokinetic Knee Extension and Flexion in Subjects with and without Meniscal Tears

Intertrial reliability of work measurements was studied in 19 men with a partial medial meniscal tear (ME group) and in 10 men with no history of knee injury (control group). Three maximal voluntary concentric contractions of the muscles involved in knee extension (KE) and knee flexion (KF) were performed on a dynamometer at 30° and 180°/s using a preloading protocol. The subjects moved their legs through an arc of 90 degrees, and the work produced in the constant-velocity phase between 70 and 20 degrees of KE was computed for each trial. In ME group subjects able to perform three consecutive contractions (n=12-14), high intertrial intraclass correlation coefficients (ICCs) were found (ICCs=.86-.92), except for KE work measurements at 180°/s (ICC=.67). In the control group subjects, high ICCs were obtained for KE work measurements (ICCs=.87 and .95), whereas the low ICCs obtained for KF work measurements (ICCs=.64 and .79) increased to .86 and .93 when the first trial was removed. In both groups, a significant increase was found over the trials for KF measurements at 180°/s and KE measurements at 30°/s, but work measurements were shown to peak at the second trial. The results of this study suggest that the work produced on the second trial reflects a subject's maximal capacity. [Durand A, Malouin F, Richards CL, Bravo G. Intertrial reliability of work measurements recorded during concentric isokinetic knee extension and flexion in subjects with and without meniscal tears. Phys Ther. 1991;71:804-812.]

Key Words: Concentric contractions, Isokinetics, Knee joint, Menisci, Reliability.

The widespread use of isokinetic dynamometers in clinical settings for assessing the capacity of muscles to produce maximal torque during constant-velocity movement has given rise to many studies that have investigated the methodological aspects associated with the testing protocol. One of the main concerns of these studies is the reproducibility of torque or work measurements in subjects without knee impairments. For instance, for maximal concentric knee extension at 180°/s, Johnson and Siegel found that three submaximal warm-up contractions, followed by three maximal contractions, were
needed before reliable peak torque measurements could be recorded within a testing session (intraclass correlation coefficient [ICC] ≥ 93).

Sawhill et al.,5 who examined variability between subsequent trials, suggested that at least four maximal contractions be performed to record representative data of concentric knee extensions (KEs) and flexions (KFs) at velocities of 200°, 300°, and 400°/s. More recently, Wessel et al.6 concluded that, during isokinetic dynamometric testing, subjects should have a practice session before the first test evaluation. As an alternative, they also suggested that the maximal work produced over four or six trials be used as the criterion measure of the subject's maximal performance, given the high value of between-week ICCs for all four conditions tested (ie, ICCa=.84 for measurement of work at concentric and eccentric knee extensor contractions at 60° and 180°/s). A common feature of these studies is the need for nonimpaired subjects to perform at least three maximal contractions before reliable peak torque or work measurements can be recorded.

In contrast, the reliability of torque and work measurements has not been extensively evaluated in patients with musculoskeletal disorders.6,7 Finucane et al.6 however, reported high intertrial ICCs (ICCs=.95-.97) and moderate to high between-session (performed on the same day) ICCs (ICCs=.75-.95) when three isometric KE and KF contractions were evaluated in patients with connective tissue disease. More recently, Wessel and Galbraith,7 recommended that one practice session be made before recording concentric work during KE movements in patients with rheumatoid arthritis (RA), given a significant difference in work measurements recorded between the first session and the two subsequent testing sessions.

Questions remain, however, about the applicability of reliability findings based on isometric contractions to isokinetic movement and about the applicability of reliability findings obtained for nonimpaired subjects and patients with chronic diseases to patients with more acute musculoskeletal disorders. For instance, acute musculoskeletal problems may impede knee movements and consequently affect the reliability of torque or work measurements taken during isokinetic movements. Furthermore, patients with pain, swelling, or marked muscle weakness might not be able to perform at least three maximal contractions prior to taking the measurements, as recommended for nonimpaired subjects. Last, for practical reasons, such as when testing prior to surgery, it is almost impossible to retest the patients 1 day or 1 week later. Moreover, even if a retest could be carried out, it would always be difficult to interpret the data, given the evolving pathological state of the patients between the two testing sessions.

One alternative is to compare the reliability of the work measurements obtained in the patients within a testing session (intratrial) with that of work measurements obtained in nonimpaired subjects. Such a comparison would indicate whether intertrial reliability levels are similar in patients and nonimpaired subjects. It could also show the reliability of work measurements when a smaller number of trials (eg, three) are made and finally which of these trials best reflects the subject's maximal work capacity.

The aims of this study were (1) to describe the capacity of patients who have been diagnosed as having meniscal tears to perform three consecutive maximal isokinetic concentric KE and KF movements at 30° and 180°/s, (2) to compare intertrial reliability levels for the patients with those of subjects without meniscal tears, and (3) to determine the trial that best represents the maximal work production of subjects in both groups.

Subject and Design

The following subjects participated in this study: 19 men (age=38.0±8.1 years [X±SD], range=24-49 years; height=170.6±7.1 cm, range=156.5-180.5 cm; and weight=72.2±8.2 kg, range=58.0-85.0 kg) who had been diagnosed as having a medial meniscal tear, which was later confirmed by arthroscopic surgery (duration of symptoms before surgery=14.7±26.6 months, range=0.3-120.0 months) (ME group), and 10 men (age=33.0±5.1 years, range=27.0-45.0 years; height=173.2±6.0 cm, range=165.0-181.5 cm; and weight=72.1±6.4 kg, range=60.0-79.0 kg) with no history of knee injury (control group). The ME group subjects were recruited from the Orthopedic Department of the Hôpital de l'Enfant-Jésus in Québec City (Québec, Canada). The ME group was later divided in two groups: ME group1 subjects (n=10) were able to complete the evaluation procedures, and ME group2 subjects (n=9) were unable to complete the evaluation procedures. The majority of the subjects were workers whose daily routine involved walking and lifting light loads (eg, construction workers, mechanics). According to a modified classification* of the Saltin and Grimby activity scale, these workers performed activities corresponding to a rating of 2 (in a three-level scale) in terms of functional demands on the lower extremities. Torque capacity of the affected leg was evaluated prior to arthroscopic surgery in the ME group subjects and of one leg (determined randomly) in the control group subjects. All subjects gave written informed consent to participate in this study.

Evaluation Procedures

Maximal torque values produced by the knee extensor and flexor muscles during isokinetic movements at 30° and 180°/s were measured using a computer-controlled Kin-Com® dynamometer. The torque signals from the dynamometer were calibrated with known weights prior to each
evaluation. None of the subjects had previous experience with this dynamometer. Subjects were seated on a specially designed chair (with an adjustable backrest to control for hip angle and rectangular openings in the seat to permit the recording of hamstring muscle electromyographic [EMG] activity), with the hip flexed 120 degrees and with restraining straps placed across the trunk, hips, and thigh being evaluated. This chair and fixation system provides more stability to the trunk than the conventional Kin-Com® system. The axis of the dynamometer was aligned with the lateral epicondyle when the knee was flexed from 80 to 85 degrees. A shin pad was secured just above the malleoli to allow free movement at the ankle. To minimize discomfort during the test session and to reduce the risk of injury, each experimental procedure was preceded by a warm-up period consisting of 10 submaximal contractions in which the subject was requested to exert increasing effort from an initial minimal effort.10 After performing these contractions, subjects rested for 2 minutes before the test session started.

Maximal voluntary concentric contractions were performed at a constant velocity of 30° and 180°/s through an arc of 90 degrees, with zero corresponding to full extension of the knee. Knee extension movements at low (30°/s) and then high (180°/s) velocity were always tested prior to KF movements. For each of these conditions, three contractions interspersed by 1-minute rest periods were recorded. A 2-minute rest period separated the different conditions. During the isokinetic movements, the subjects had to maintain a minimum force of 50 N against the shin pad for movement to continue. This minimal force was set in part to ensure that the movement arrested if the subject stopped pushing against the dynamometer lever arm because of pain or discomfort and in part to prevent movement initiation attributable solely to the weight of the leg during the KF movements. The control of the acceleration and deceleration phases was set to medium. The isokinetic movements were preceded by a maximal preloading isometric contraction with a duration of about 2 seconds. The purpose of this contraction was to allow time for the contractile tension to rise before movement was permitted, thus eliminating the influence of the force-development phase on the early part of the torque-angle curve recorded during the isokinetic movements.11,12 Instructions to the subjects were standardized and always given by the same person (AD). Verbal feedback was given to encourage maximal effort.13 The EMG activity of the vastus medialis, vastus lateralis, and medial hamstring muscles was recorded during all the voluntary contractions.

The torque values produced during voluntary contractions were corrected for passive torque attributable to the weight of the leg segment, the shin pad, and the shin pad lever arm, as well as for torque induced by the joint structures.13,14 These passive torque values were obtained by measuring the resistive torque to passive knee movements at 30°/s in the sitting position. Passive measurements were made throughout a KE-KF cycle prior to the voluntary contractions. During these passive movements, the surface EMG activity of the vastus medialis, vastus lateralis, medial hamstring, and medial gastrocnemius muscles was recorded to ensure that the subject was relaxed. Mean values derived from three repetitions were used to calculate the torque correction, angle for angle, throughout the movements. The torque values obtained during voluntary contractions and passive knee movements were recorded using a data-acquisition program developed in our laboratory. The signals from the Kin-Com® were fed to an IBM PC-AT®-compatible computer and sampled at a frequency of 10 Hz during the isometric contractions and at a rate that was triggered by the angle signal at each degree of movement during the isokinetic contractions. Work values were subsequently computed according to the specific angular range selected.

A clinical examination was carried out prior to the testing session in all subjects to estimate the stability of the ligaments, pain (evaluated with the linear analogue scale or the pain index introduced by Melzack15), swelling, range of motion (ROM), and patellar integrity. This examination established a clinical contact with the patient and was used as an additional screening process to eliminate patients with other knee problems.

**Data Analysis**

For each condition, only data for subjects who were able to successfully complete three consecutive maximal contractions (trials) were included in the statistical analysis. For a trial to be considered successful, the isokinetic movement had to be completed over a ROM of 90 to 10 degrees for KE movements and of 5 to 90 degrees for KF movements. These criteria for inclusion ensured that the segment of the torque-angle curve between 70 to 20 degrees was not affected by the acceleration and deceleration phases of the dynamometer.12,17 From the torque-angle curves recorded, the work produced over 70 to 20 degrees of movement was computed for all four conditions.

Intraclass correlation coefficients (type 2,1)18 and their 95% lower confidence limit19 were computed to determine the reproducibility of the measurements between trials for each muscle group, for both velocities and for each group of subjects. The estimation of these coefficients was based on a two-way analysis-of-variance (ANOVA) procedure. Intraclass correlation coefficients from .80 to 1.00 were considered very reliable, those from .60 to .79 were considered moderately reliable, and those lower than .60 were considered of questionable reliability.20 To examine simultaneously the effect of group and trials, a
multivariate analysis of variance (MANOVA) was performed to determine whether a significant difference existed between the subsequent trials and between the ME group and the control group. When a significant difference was observed between the subsequent trials or between the groups, the Fisher's Exact Probability Test was chosen to compare the pain presence or absence of pain constituted nominal data. Because the presence or absence of pain constituted nominal data from two independent samples of small size (ME group1 and ME group2), the Fisher's Exact Probability Test was chosen to compare the pain distribution between the groups. Last, coefficients of variation were calculated to examine the intertrial variability.

Results and Discussion

As expected, not all ME group subjects were able to perform three consecutive maximal contractions. Indeed, only 10 subjects did so for all four conditions (ME group1). Of the other 9 subjects (ME group2), 5 subjects completed three consecutive contractions in at least one condition (Tab. 1). Among the 4 subjects who were unable to complete three consecutive trials, 2 subjects performed two or fewer trials, and 2 subjects were unable to complete at least one trial for any condition.

The capacity of the ME group1 subjects to perform three consecutive maximal contractions cannot apparently be related to pain or other clinical signs. In both ME groups, swelling was present in 40% of the subjects and 30% had a restricted ROM in either KE or KF movements. Moreover, even if the proportion of subjects reporting slight to moderate pain during the testing for ME group1 (4/10, 40%) was smaller than that for ME group2 (6/9, 67%), the difference was not statistically significant (P>0.05). As expected, all of the control group subjects were free of swelling and had full knee ROM, whereas only one control group subject reported slight pain in his knee during the evaluation.

Intraclass correlation coefficients are reported in Table 2 with their 95% lower confidence limit in order to better illustrate the variability of the point estimate. In the ME group subjects, except for KE work measurements at 180°/s, ICC values computed for the three trials ranged from .86 to .92, indicating very reliable measurements. Although the control group subjects' ICC values indicated high reliability for KE work measurements at both velocities (ICCs=.87 and .95), lower reliability levels were found for KF work measurements (ICCs=.64 and .79). The lack of reliability of measurements obtained in some conditions is likely related to the trials, random error, or the low intersubject variability. The high variance attributable to the trials for KE measurements at 180°/s in the ME group as compared with the control group (Tab. 3) suggests that the lower reliability level is most likely associated with the trials. The trials, however, did not seem to be the sole source of variation for KE measurements at 30° and 180°/s for the control group subjects (Tab. 3).

To determine whether the measurement obtained during one of the trials was responsible for the lower reliability levels obtained, the ICCs were computed after eliminating the first, second, or third trial. This analysis indicated that, with the first trial excluded, the ICCs were generally equal to or higher than .93. For KE measurements at 30°/s in the control group, however, the ICC increased to .86, whereas for KE measurements at 180°/s in the ME group, the ICC remained low (Tab. 2). The effect of the first trial on reliability seems particularly determinate for KF conditions in the control group. In that group, the ICC values generally increased (Tab. 2), and the variance attributable to trials markedly decreased (Tab. 3) when only the second and the third trials were computed. It was not possible to associate the low reliability observed for KE measurements at 180°/s in the ME group to any one of the trials. The variance attributable to trials always remained high, regardless of the combination of trials. These results thus indicate that the effects of the first trial on reliability are different according to the group of subjects and the movements being tested.

Mean work values (in joules) computed for both groups for the three trials in each of the four conditions are illustrated in the Figure. For all conditions, the mean work value of the first trial is lower than those of the last two trials. For both groups of
Table 2. Intraclass Correlation Coefficients (ICCs) for Intertrial Reliability of Measurements of Knee Extension and Flexion at Movement Velocities of 30° and 180°/s

<table>
<thead>
<tr>
<th>Groupb</th>
<th>Knee Extension</th>
<th>No. of Subjects Completing All Three Trials in Each Condition</th>
<th>Knee Flexion</th>
<th>No. of Subjects Completing All Three Trials in Each Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-2-3°</td>
<td>2-3°</td>
<td>1-2-3</td>
<td>2-3</td>
</tr>
<tr>
<td>ME</td>
<td>.86 (.71)</td>
<td>.93 (.83)</td>
<td>13</td>
<td>.87 (.75)</td>
</tr>
<tr>
<td>30°/s</td>
<td>.67 (.42)</td>
<td>.74 (.43)</td>
<td>12</td>
<td>.92 (.78)</td>
</tr>
<tr>
<td>180°/s</td>
<td>.87 (.69)</td>
<td>.96 (.89)</td>
<td>10</td>
<td>.64 (.35)</td>
</tr>
<tr>
<td>Control</td>
<td>.95 (.89)</td>
<td>.93 (.81)</td>
<td>10</td>
<td>.79 (.57)</td>
</tr>
</tbody>
</table>

*ICC type (2,1)­18; 95% confidence intervals shown in parentheses.
*b~ group (n=19)=patients with partial medial meniscal tears; control group (n=10)=subjects with no history of knee injury.
*cCombination of trials.

subjects, however, the ANOVA showed a significant intertrial difference only for KE measurements at 30°/s and KF measurements at 180°/s (P<.05). The inability to detect a significant difference for the two other conditions could be due to a lack of statistical power. In the conditions in which a significant difference was observed, the post hoc analyses revealed a linear increase in the work measurements over the trials, but the work values tended to peak at the second trial. No significant difference was observed between the last two trials (P>.05).

These findings suggest that the second and the third trials represent comparable work measures for a given subject. Furthermore, the mean intertrial CV computed for the three trials never exceeded 10.3% for all conditions and both groups of subjects, and generally even smaller variations were observed between the second and the third trials (Tab. 4). The variation between the first and second trials also was small, as demonstrated by CVs that never exceeded 8.7%. A significant difference (P<.05) for the three trials was found between the control group and the ME group only for the work measurements recorded during KE movements at 30°/s, a condition that proved to be very reliable in both groups.

Table 3. Estimated Components of Variance for Two-Way Analysis of Variance for Measurements of Knee Extension and Flexion at Movement Velocities of 30° and 180°/s

<table>
<thead>
<tr>
<th>Groupb</th>
<th>Knee Extension</th>
<th>Knee Flexion</th>
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<tbody>
<tr>
<td></td>
<td>30°/s</td>
<td>180°/s</td>
</tr>
<tr>
<td></td>
<td>1-2-3°</td>
<td>2-3°</td>
</tr>
<tr>
<td>ME</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2t</td>
<td>356.8</td>
<td>0.4</td>
</tr>
<tr>
<td>2s</td>
<td>1742.1</td>
<td>1159.2</td>
</tr>
<tr>
<td>2e</td>
<td>67.8</td>
<td>42.6</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2t</td>
<td>329.8</td>
<td>23.4</td>
</tr>
<tr>
<td>2s</td>
<td>1948.0</td>
<td>1332.2</td>
</tr>
<tr>
<td>2e</td>
<td>69.3</td>
<td>26.9</td>
</tr>
</tbody>
</table>

*aNumber of subjects completing the three trials in each condition shown in parentheses.
*bME group (n=19)=patients with partial medial meniscal tears; control group (n=10)=subjects with no history of knee injury.
*cCombination of trials.
The results of this study indicate that very reliable intertrial work measurements (ICC > .86) were obtained for subjects in the ME group (Tab. 2), except for KE measurements at 180°/s. Moreover, the intertrial reliability of KF work measurements at both movement velocities was even higher for the ME group than for the control group. In the control group, intertrial reliability was clearly improved (ICC > .86) by eliminating the first trial from the data analysis (Tab. 2). On the contrary, removal of any one of the three trials did not much improve the intertrial reliability of KE measurements at 180°/s for the ME group (Tabs. 2, 3).

It was surprising to find high intertrial reliability for most conditions in both groups, given the small number of trials performed in each condition. A possible explanation for such findings is the use of preloading. As explained previously, an isometric contraction preceded the isokinetic movement. This preloading may have played a preparatory role equivalent to the use of maximal isokinetic movements to improve intertrial reliability. Indirect support for this hypothesis is the high ICC (ICC = .95) obtained for KE measurements at 180°/s in the control group in this study, which was comparable to that reported by Johnson.

Figure. Mean work values (in joules), ±1 standard deviation, computed for each of the three trials in each of the four test conditions for the patients with a meniscal tear (ME group, n=19) and for the subjects with no history of knee injury (control group, n=10). Graphs show the results for knee extension movements at 30°/s (A) and 180°/s (B) and for knee flexion movements at 30°/s (C) and 180°/s (D). The number of subjects completing the three trials for each condition is given in parentheses.
...and Siegel when the last three trials were used (ICC = .94) and even higher than that obtained by Wessel et al when six trials were compared (ICC = .88).

Because the ME group subjects usually had comparable or even higher ICCs than the control group subjects and KE measurements at 180°/s were the most reliable measurements in the control group, it was surprising to find the lowest intertrial reliability for those measurements in the ME group (Tab. 2). This finding and the fact that the ICC values and the variance attributable to the trials could not be changed by eliminating any one of the trials (Tabs. 2, 3) suggest that the level of difficulty required to reproduce the three maximal contractions for KE at 180°/s differed among the ME group subjects and that individual performance thus varied accordingly.

Muscle weakness alone was not apparently responsible for the low ICCs found in the ME group during KE movements at 180°/s, because despite the deficit in KE work measurements at 30°/s in the ME group as compared with the control group, high intertrial ICCs were obtained. Knee extension work measurements obtained at the higher velocity of movement (ie, 180° versus 30°/s), however, may have revealed another particularity of the functional impairment resulting from the meniscal tear. It is not possible to determine from the results of this study whether the sensation associated with the transition from the maximal isometric contraction (ie, pre-loading) to the fast (ie, 180°/s) concentric contraction affected the capacity of the ME group subjects to cope with faster KE movement. Only a study comparing the performance of patients who have a meniscal tear with and without the use of pre-loading could answer this question. Although the low intertrial reliability observed for KE measurements at 180°/s in the ME group seems to reflect an underlying biomechanical change, this low reliability may be responsible for not disclosing deficits in KE work measurements at this movement velocity.

Given the high intertrial reliability for KF measurements in the ME group, the low reliability levels in the control group for these conditions was not expected. Removing the first trial from the data analysis, however, particularly improved the ICC values computed for KF movements at 30° and 180°/s (Tab. 2), and such an improvement was associated with a reduction in the component of variance originating from the trials (Tab. 3). The small inter-subject variations for KF conditions, which make them more sensitive to intertrial variation, no doubt contributed to these differences. These findings, therefore, suggest that the first trial may be misleading and thus perhaps should be rejected. The mean work value from the first trial tended to be lower than those from the last two trials (Figure). This finding may be attributed to a learning effect present when muscle contractions are repeated. This assumption is substantiated by the fact that, in both groups of subjects, eliminating the first trial from the data analysis improved ICCs mainly for the low-velocity KE and KF conditions, which were performed prior to their corresponding high-velocity conditions.

In this study, we assessed the reliability of work measurements taken on a small sample of patients with partial meniscal tears and subjects with no history of knee injury. Because of the small number of subjects involved, it is important to report the confidence limits in order to take into account the variability of the point estimate. As shown in Table 2, a high ICC was not necessarily associated with a correspondingly high 95% lower confidence limit when the three trials in each condition were considered in the data analysis. Interestingly, when the first trial was eliminated, the 95% lower confidence limits were generally higher than 80%, suggesting that the probability of ob-

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### Table 4. Mean Coefficients of Variation for Interttrial Variability (in Percentages) of Measurements of Knee Extension and Flexion at Movement Velocities of 30° and 180°/s

<table>
<thead>
<tr>
<th>Group</th>
<th>Knee Extension</th>
<th>No. of Subjects Completing All Three Trials in Each Condition</th>
<th>Knee Flexion</th>
<th>No. of Subjects Completing All Three Trials in Each Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30°/s</td>
<td>7.1</td>
<td>1-2</td>
<td>7.8</td>
<td>1-2</td>
</tr>
<tr>
<td>180°/s</td>
<td>8.2</td>
<td>1-2</td>
<td>10.3</td>
<td>1-2</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30°/s</td>
<td>6.0</td>
<td>1-2</td>
<td>5.9</td>
<td>1-2</td>
</tr>
<tr>
<td>180°/s</td>
<td>3.4</td>
<td>1-2</td>
<td>4.0</td>
<td>2-3</td>
</tr>
</tbody>
</table>

*ME group (n=19)=patients with partial medial meniscal tears; control group (n=10)=subjects with no history of knee injury.

*Combination of trials.
serving comparable results between the second and the third trials is high. Exceptions to these results were obtained for KE measurements at 30°/s in the ME group and for KF measurements at 30°/s in the control group. The low 95% lower confidence limit for the ME group (ie, 43) can be explained by the fact that the variability originating from the trials remained high when the first trial was eliminated from the data analysis (Tab. 3). For KF measurements at 30°/s in the control group, the 95% lower confidence limit improved by eliminating the first trial (Tab. 2). The component of variance originating from the error, however, remained relatively high (given the low inter-subject variability), resulting in a 95% lower confidence limit of 61. For these two conditions, the reliability of the measurements would probably be improved by performing a greater number of trials.

From our results, it was not possible to associate clinical findings to the ME group subjects' capability of performing three or fewer trials. This may be due to the small number of subjects evaluated. It can also be argued that the subjects in ME group2 could not complete all three trials in all four conditions because movements at 30°/s exacerbated their meniscal symptoms. Data in Table 1, however, suggest that the inability to complete three consecutive trials was not related to the velocity of movement. Indeed, similar results were obtained for movements at 180°/s, when the joint pressures are less. Furthermore, if the meniscal symptoms were exacerbated by the movements at 30°/s, one would expect greater intertrial variability and consequently lower ICCs in the subjects who completed three trials. Conversely, very reliable work measurements were obtained (Tab. 2), and the intertrial variability observed in the ME group for movements at 30°/s was in the same order of magnitude as that observed in the control group (Tab. 4).

Because of the small number of ME group subjects (n=4) who were able to perform only two trials, no attempt was made to compare their corresponding ICCs with those of ME group subjects who were able to complete three consecutive trials. As demonstrated by the mean intertrial CVs, the percentages of variation never exceeded 10.3% and even less variability was observed between the second and the third trials (Tab. 4). These findings, the generally high intertrial reliability, and the fact that work measurements were not significantly different between trials or tended to peak after the second trial suggest that two trials may be sufficient to assess work capacity in patients with meniscal tears.

In this study, the subjects moved their legs through an arc of 90 degrees and the work produced in the constant-velocity phase between 70 and 20 degrees of KE was used as the representative variable rather than the peak torque or work produced over the full ROM tested. The reasons were twofold. First, this segment corresponds to a range of the torque-angle curve in which the work values are not affected by the acceleration and deceleration phases of the dynamometer.12 Second, given the fact that the KE dynamic neuromuscular deficit covers a large portion of the torque-angle curve in patients with meniscal tears, this variable is more representative of the deficit than the peak torque value alone.22

Clinical Implications

The assessment of the capacity to produce torque or work is a frequent and important task carried out by physical therapists. Isokinetic dynamometers are extensively used for this purpose. To be meaningful and useful, however, measurements taken with these devices must be reliable. This study demonstrated that reliable intertrial work measurements can be obtained in subjects with and without meniscal tears with the Kin-Com® dynamometer when using a standardized protocol. Such measurements can thus be used to characterize the neuromuscular capacity of the patients evaluated or can serve as reference data to evaluate the effects of a surgical procedure such as arthroscopic meniscectomy.

The results of this study are not directly applicable to other patient populations or to the postoperative state of the patients evaluated. This protocol, however, provides a template for clinicians by which to evaluate similar populations of patients. Clinicians should note that a specially designed chair and data-acquisition system were used in this study. It is not known whether the commercially available version of the chair would yield equally reliable measurements.

The results of dynamometric tests reflect not only the capacity of a muscle to produce force but also its capacity to activate the motor units. It may thus be more appropriate to refer to the evaluation of the neuromuscular performance of subjects. Consequently, when torque or work deficits are found in patients, as in this study for KE measurements at 30°/s in the ME group, such deficits cannot be attributed solely to defects in the muscle.52 Indeed, pain or swelling may have reflexly inhibited the muscles, resulting in lower torque or work values. Techniques using electrical stimulation, such as the interpolated twitch technique, could conceivably shed light on the relative contributions of deficient motor unit activation or muscle weakness. In clinical practice, physical therapists should keep in mind that changes in reflex inhibition may result in rapid increases in torque or work values associated with the disappearance of pain or swelling. Reflex inhibition was probably not involved during KF movements in this study, because comparable work values were obtained for both groups of subjects.

Conclusions

The high ICCs computed for the work measurements recorded during maximal concentric isokinetic knee movements indicate that the protocol used in this study provided reproducible measurements, not only in the control group but also in the ME group subjects who were able to perform three
consecutive trials. Exceptions to these findings were found for KE measurements at 180°/s in the ME group and for KE measurements at both movement velocities in the control group. The elimination of the first trial in the data analysis improved the level of reliability in the control group, but it did not increase the ICC value for KE measurements at 180°/s in the ME group. The ME group's lower reliability level is most likely associated with their functional disability, suggesting that the inability to reproduce maximal effort at 180°/s could be characteristic of this population of patients. These data also suggest that the second trial may best represent the maximal neuromuscular performance of patients with meniscal tears, given the difficulty for them to complete three consecutive trials. This conclusion can be extended to subjects without meniscal tears within the present testing protocol.

Acknowledgments

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References