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Repeatability of Maximum Knee Muscle Strength Measurements Determined using a Discrete and a Continuous Protocol for Isokinetic Testing on the HUMAC NORM Dynamometer

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Abstract

The purpose of this protocol evaluation was to compare the repeatability of a discrete and a continuous protocol for determining maximum muscular strength on the HUMAC NORM dynamometer. Eight subjects performed concentric knee extension and flexion at 60 degrees per second to test muscular strength. Each subject performed two different testing protocols twice with different operators. The protocols were 1) Continuous Protocol – the subject performed five repetitions of concentric knee extension and flexion continuously at a rate of 60 degrees per second in the same test trial – and 2) Discrete Protocol – the subject performed five repetitions of concentric knee extension, with brief periods of rest between repetitions, at a rate of 60 degrees per second in one test trial and then performed another trial of five repetitions to test concentric knee flexion. The comparison of the discrete and continuous protocols was inconclusive. The discrete protocol was slightly more repeatable during knee extension, with a percent difference of 7.28% compared to a percent difference of 9.70% for the continuous protocol. However, when subjects performed knee flexion, using the discrete protocol resulted in a percent difference of 3.78%, which indicated slightly lower repeatability than the 2.98% found with the continuous protocol. Therefore, no meaningful difference was found between the two protocols.

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Introduction

The Exercise Physiology and Countermeasures (ExPC) Project at NASA Johnson Space Center is responsible for assessing muscle strength in crewmembers to evaluate the effectiveness of exercise countermeasures performed during space flight, as well as to track the success of their rehabilitation after landing as described by the Medical Evaluations Document Volume B (MedBs). Currently, crewmember muscular strength is assessed before and after space flight using a discrete testing protocol on the HUMAC NORM isokinetic dynamometer (CSMi, Stoughton, MA). A discrete testing protocol requires that only flexion or only extension is performed in a given test trial. However, the HUMAC NORM isokinetic dynamometer is a "continuous dynamometer." This means the suggested use of this machine is a continuous format in which participants perform flexion and extension motions without rest in a given test trial. Furthermore, ExPC has considered purchasing a new continuous dynamometer and may consider the results of this repeatability evaluation to determine the feasibility of switching from a discrete to continuous protocol. The purpose of this protocol evaluation was to compare the repeatability of determining maximum muscular strength on the HUMAC NORM dynamometer using a discrete and a continuous protocol.

Methods

Subjects

Four men and four women (37.9 ± 4.5 yr), all healthy nonsmokers, participated in the protocol evaluation, which was reviewed and approved by the NASA Committee for the Protection of Human Subjects. All test subjects successfully passed a modified Air Force Class III physical exam and gave informed consent before they participated in the protocols of this evaluation.

Protocol

The subjects performed concentric knee extension and flexion at 60 degrees per second to test muscular strength. In concentric exercise, the subject moves the lever arm of the isokinetic testing device, but the device controls the speed of the movement so that it is constant.

Depending on the data collection session, the subject performed one of two different testing protocols:

1) Continuous Protocol – The subject performed five repetitions of concentric knee extension and flexion continuously at a rate of 60 degrees per second in the same test trial.
2) Discrete Protocol – The subject performed five repetitions of concentric knee extension with brief periods of rest between repetitions at a rate of 60 degrees per second in one test trial, and then performed another trial of five repetitions to test concentric knee flexion.

In total, each subject completed four test sessions: two continuous protocol sessions and two discrete protocol sessions. Operationally, it is common to have different operators for subsequent testing of the same individual; therefore, all subjects had one continuous and one discrete protocol session with each of two operators. During each session, the subject was familiarized with the isokinetic testing device and all testing procedures. Each test was preceded by an appropriate warm-up and practice before data collection began. Testing was always performed with the right leg, and each total session time was less than 30 minutes. Sessions were separated by at least 2 days.

It was also of interest to determine if one of the protocols was more efficient from a time perspective than the other. During a practice session for this study, both protocols were timed while being performed by two different operators.

Study Constraints

No intense exercise was allowed in the 24-hour period immediately before any of the testing sessions. In addition, all subjects were asked to report to the testing personnel any new conditions that might have affected their safe participation in these tests and/or the data obtained during this study.

Data Analysis

This evaluation was a pilot study; therefore, a formal statistical analysis was not performed on the data. To evaluate the repeatability of the maximum knee extensor and flexor strength measurements, the peak torque performed within each 5 repetition rest was used to calculate a percent difference (Equation 1) for each subject in the discrete protocol and the continuous protocol. Then the percent difference for all subjects was averaged for each protocol.

$$\text{Percent Difference} = \left| \frac{x_1 - x_2}{(x_1 + x_2)/_2} \right| \times 100 \qquad \text{Equation 1}$$

Results

All eight subjects successfully completed all testing sessions. The largest percent difference between tests occurred during knee extension with the continuous protocol (9.70%), whereas the smallest percent difference occurred during knee flexion with the continuous protocol (2.98%). This indicates that the operational margin of error for MedB 5.3 knee testing is about 10%. Therefore, if a change in muscular strength greater than 10% is indicated, it is likely that this difference is a physiologically meaningful difference in muscular strength. With a percent difference of 7.28%, the discrete protocol was more repeatable during knee extension than the continuous protocol, which had a percent difference of 9.70% (Figure 1). However, during knee flexion, the discrete protocol had a percent difference of 3.78%, which indicated less repeatability than the 2.98% found with the continuous protocol (Figure 1).

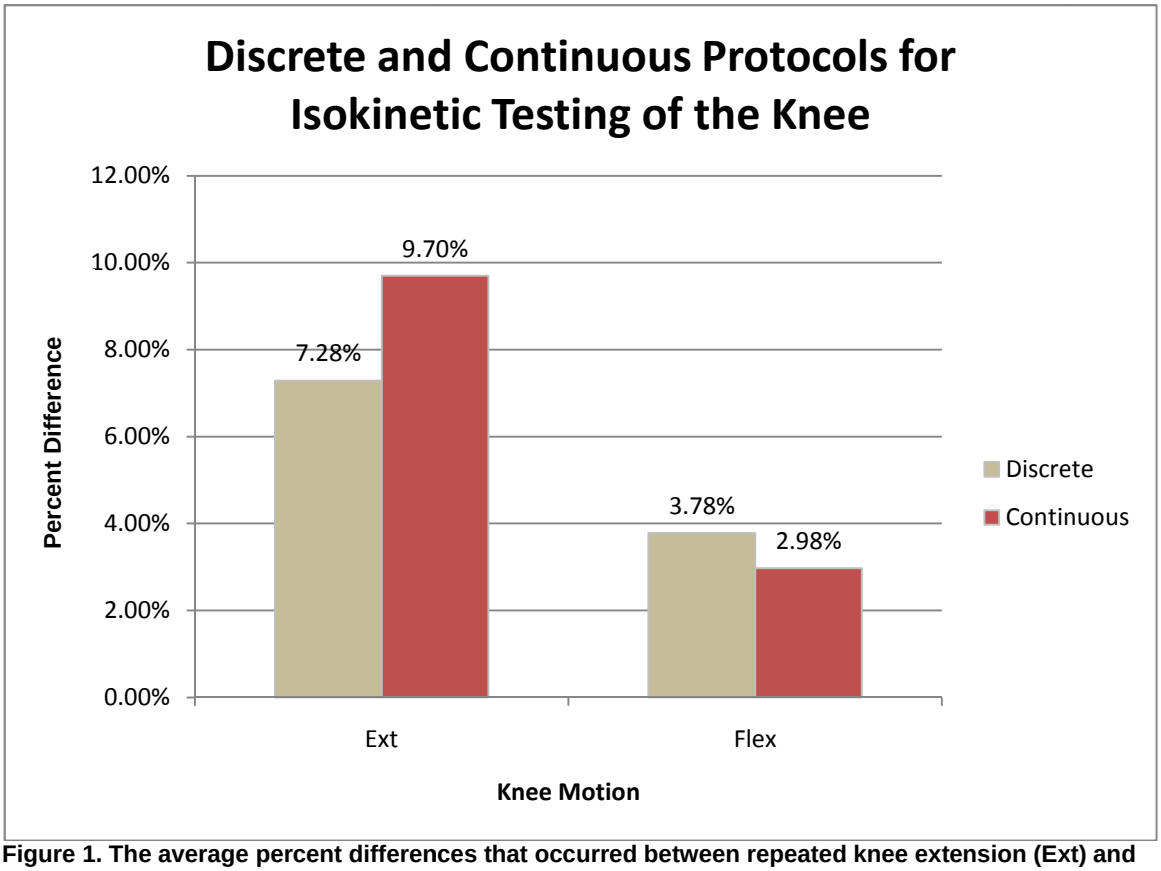
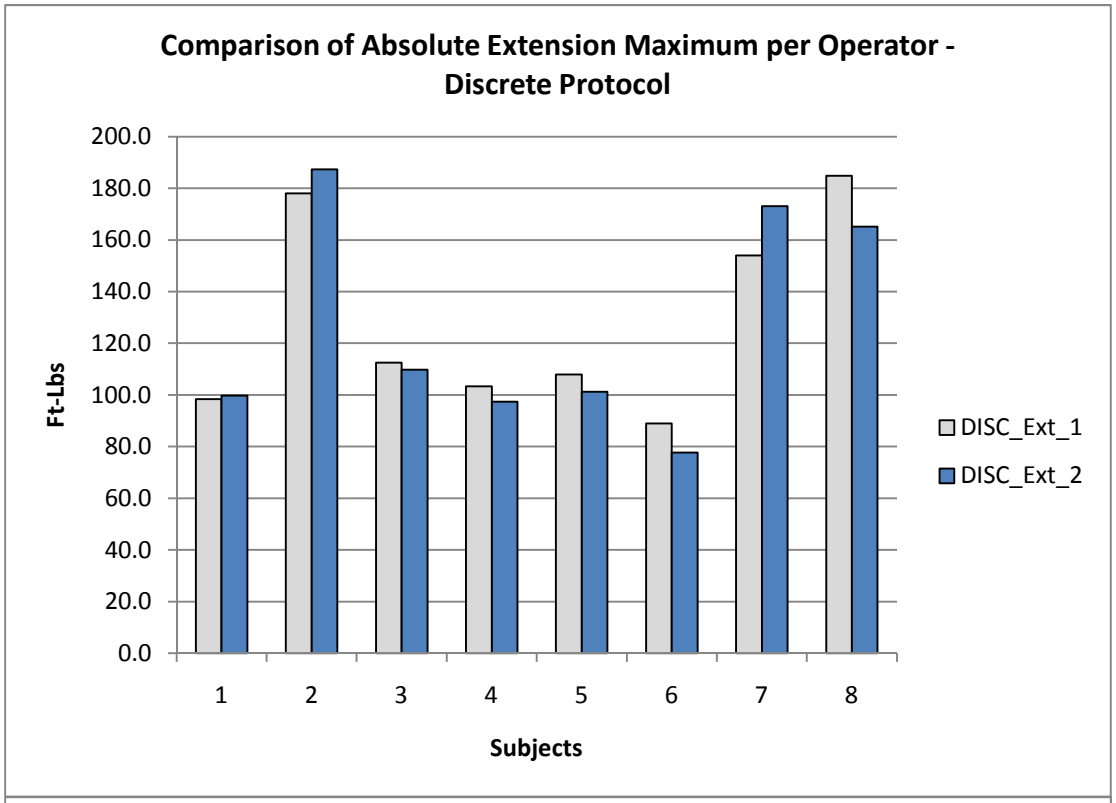


Figure 1. The average percent differences that occurred between repeated knee extension (Ext) and flexion (Flex) maximum strength tests with the discrete and continuous protocols. Eight subjects completed two test sessions using each protocol.

Figures 2 and 3 show each subject's maximum knee flexion and extension during the discrete and continuous protocols with the two different operators for each protocol. Absolute values are presented in order to gain appreciation for the percent change values given in Figure 1. Additionally, the figure more clearly represents differences among operators. (Note that the data are actual values in foot-pounds (ft-lbs), not percent differences.)



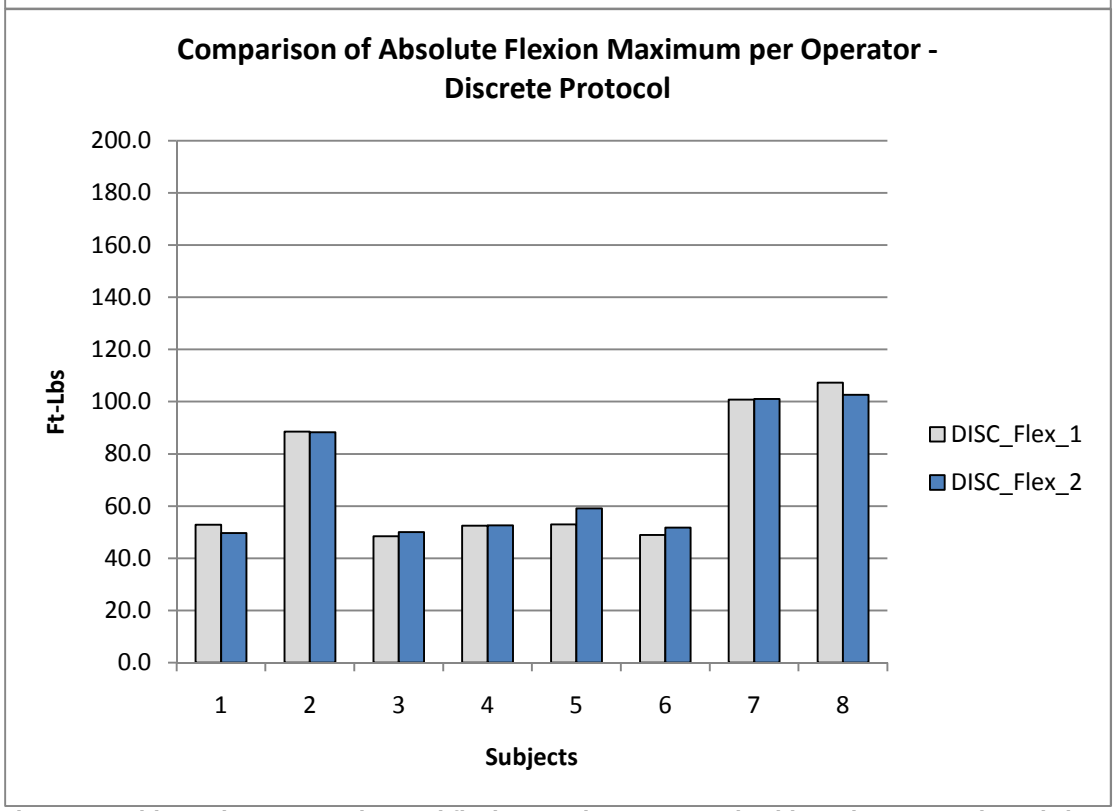


Figure 2. Subjects' knee extension and flexion maximum strength with each operator (1 and 2) during the discrete protocol.

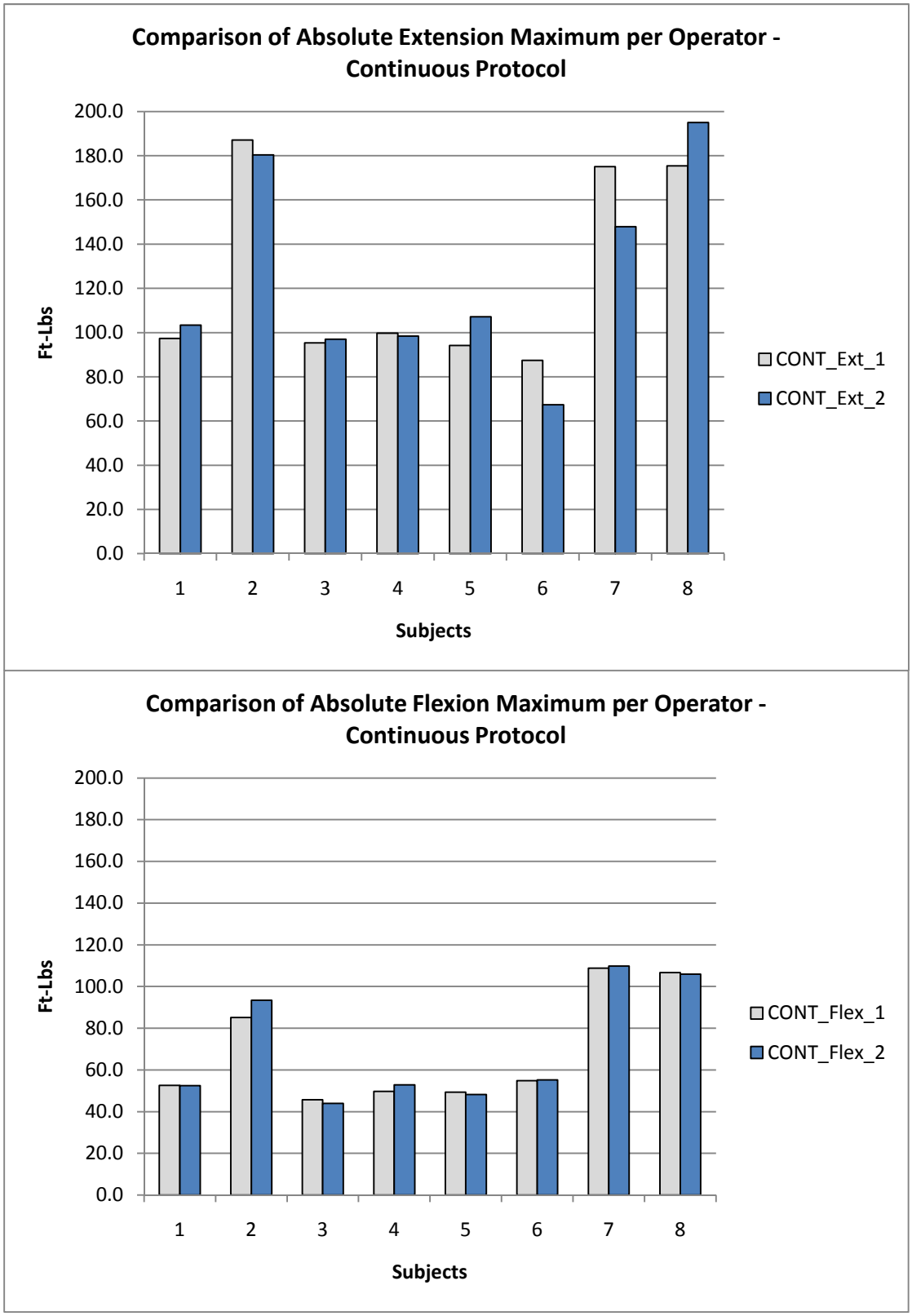


Figure 3. Subjects' knee extension and flexion maximum strength with each operator (1 and 2) during the continuous protocol.

It was difficult to find reports of other studies in which percent differences were used as the repeatability measure. However, in one report the average peak torques for all subjects were presented (Orri and Darden, 2008). To compare our data with those of Orri and Darden, we calculated the average peak torques, and resulting percent differences, for our experiment in order to make some comparison (Table 1).

Table 1. Mean (± SD) Peak Torque Values (ft-lb) and Percent Differences for Discrete and Continuous Protocols (*n* = 8)

	Discrete			Continuous		
Test	Test 1	Test 2	% Difference	Test 1	Test 2	% Difference
Right Knee						
Flexion	69.0 ± 23.6	69.4 ± 22.2	0.6%	69.1 ± 25.1	70.2 ± 26.0	1.6%
Extension	128.5 ± 35.5	126.4 ± 39.1	1.6%	126.4 ± 41.1	124.6 ± 42.0	1.4%

When assessing time, the knee exercise alone, a minimum of 5 and maximum of 10 minutes were saved by performing the continuous instead of the discrete protocol. For MedB 5.3 testing, the knee, ankle, and trunk maximal torques are recorded. It is estimated that a minimum of 15 minutes and a maximum of 30 minutes could be saved using the continuous protocol.

Discussion

The comparison of the discrete and continuous protocol was inconclusive. Thus, it is reasonable to conclude that either of these protocols may be used with similar repeatability in the evaluation of both extension and flexion knee muscular strength. It may be important to note that the methodology for this testing included a confounding factor. In the discrete protocol there is greater operator-subject interaction, and it was important to examine the affect of that interaction when testing the repeatability of the protocol. Therefore, for each protocol the test was performed with two operators as is done operationally for MedB testing. The results indicated that even with different operator-subject interactions included in the protocols, the repeatability of the discrete and continuous protocols were not significantly different.

Because this experiment was designed as pilot work, the protocol was not set up for running a formal statistical analysis. However, it was important to determine if the repeatability of the operational testing performed by the ExPC is in line with the reliability of testing reported in the published literature. It was difficult to find reports of research in which percent differences were

used as a repeatability assessment; however, two studies did provide enough information to generate values that could be compared to our investigation. Li et al. (1996) calculated percent differences between tests on a Cybex 6000 and found that differences of 9–14% occurred in peak torque of knee extension and flexion. We found differences of 3–10% between tests. Orri and Darden (2008) assessed reliability of knee peak torque with a Cybex 6000 and other commercially available isokinetic machines. They found a difference of about 2.5% between exercise sets. However, percent difference for their investigation could be calculated only after all subjects' peak torques were averaged (Table 2). The data from our study were transformed into group means to compare similar values (Table 1). Although this would not be a common method for calculating percent difference, it allowed us to make one additional comparison of our repeatability results to the current literature. The percent difference based on the average peak torques presented in Table 1 ranged from less than 1% to 2%. Therefore, our pilot study demonstrated less percent difference (that is, potentially greater repeatability) between tests than the Orri and Darden (2008) Cybex 6000 repeatability results.

Table 2. Mean (± SD) Peak Torque Values and Percent Differences for the Orri and Darden (2008) Study

	Continuous		
Test	Test 1	Test 2	% Difference
Right Knee			
Flexion	109.5 ± 29.7	112.6 ± 29.5	2.7%
Extension	160.6 ± 45.7	164.4 ± 47.0	2.3%

Conclusion

The results of this protocol evaluation indicate that the discrete and continuous protocols have similar repeatability overall. The percent difference for the discrete protocol was slightly lower during knee extension; however, the difference for the continuous protocol was slightly lower during knee flexion. Therefore, either protocol could be used with similar repeatability. Additionally, when the repeatability of these protocols was compared to repeatability found in two reliability investigations, both the continuous and discrete protocols, as performed operationally in the ExPC Project, had lower percent differences between tests.

In the interest of saving time it may be advantageous to switch from the current discrete protocol to the continuous protocol since our pilot results indicated up to 30 minutes could be saved.

References

Li, RC, Wu, Y, Maffullli, N, Chan, KM, and Chan, JL (1996). Eccentric and concentric isokinetic knee flexion and extension: a reliability study using Cybex 6000 dynamometer. British Journal of Sports Medicine, 30, 156-160.

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The purpose of this protocol evaluation was to compare the repeatability of a discrete protocol with a continuous protocol for determining maximum muscular strength on the HUMAC NORM dynamometer. Eight subjects performed concentric knee extension and flexion at 60 degrees per second to test muscular strength. Each subject performed two different testing protocols twice with different operators. The protocols were 1) Continuous Protocol – the subject performed five repetitions of concentric knee extension and flexion continuously at a rate of 60 degrees per second in the same test trial – and 2) Discrete Protocol – the subject performed five repetitions of concentric knee extension, with brief periods of rest between repetitions, at a rate of 60 degrees per second in one test trial and then performed another trial of five repetitions to test concentric knee flexion. The comparison of the discrete and continuous protocols was inconclusive. The discrete protocol was slightly more repeatable during knee extension, with a percent difference of 7.28% compared to a percent difference of 9.70% for the continuous protocol. However, when subjects performed knee flexion, using the discrete protocol resulted in a percent difference of 3.78%, which indicated slightly lower repeatability than the 2.98% found with the continuous protocol. Therefore, no meaningful difference was found between the two protocols.

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