Effect of protocol and assessment device on isokinetic peak torque of the quadriceps muscle group

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Abstract:
Various devices and test protocols have been used during isokinetic assessment of human muscle performance. The purpose of this investigation was to examine the effects of continuous and interrupted test protocols and test device on concentric quadriceps peak torque (PT) production. PT was measured via two commonly employed isokinetic test devices (Cybex II and Kin-Corn) and test protocols (interrupted (1) and continuous (C)). Thirty-one. male subjects (x age 23.0 ± 2.07 years, x wt 78.2 ± 12.2 kg, x ht 177.8 ± 6.45 cm) were tested at 1.08 rad/s (60°/second), 48 h apart on each device in random order. Because the devices correct for gravity differently, gravity correction was eliminated from all test conditions. Preload and damp were applied in order to replicate clinical protocols as closely as possible. Intraclass correlation coefficients (2,3) (and standard errors of measurement) were 0.88(7.52 N , m) (I) and 0.91 (7.04 N , m) (C) for the Kin-Corn, and 0.98 (3.30 N , m) (I) and 0.92 (8.42 N. m) (C) for the Cybex. A 2 x 2 within subjects ANOVA demonstrated significant differences between Cybex (damped) and Kin-Corn (preload) PT measures (P 5 0.05). An interaction for device x protocol demonstrated greater peak torque values for the I protocol (Kin-Corn: 199.1 ± 44.9 N. m, Cybex: 181.7 ± 35.0 N .m) than for the C protocol (Kin-Com: 182.2 ± 35.5 N m, Cybex: 183.3 ± 33.9 N -m) (P < 0.05) for the Kin-Com although the Cybex values were the same. Although both the interrupted and continuous protocols demonstrate high reliability, the interrupted protocol results in higher quadriceps PT values for the Kin-Com. We conclude that selection of test protocol influences assessment of quadriceps PT when using the Kin-Com isokinetic dynamometer.

1. INTRODUCTION

Isokinetic measurement of human muscle performance has become an important evaluation and training tool used by sports medicine professionals in clinical and research settings. Over the past several years there has been a proliferation of isokinetic devices, each utilizing different means for correcting for the effects of gravity and compensating for inertial effects. Subject stabilization, mechanical structures, software, modes of exercise, available angular velocity control, and servomechanisms also vary among devices. There are inherent problems in making comparisons between data collected by systems produced by the same manufacturer [1,16] and even more in comparing data gathered from systems of different manufacturers [3,5,17,21].

Although the studies examining different aspects of isokinetic exercise are increasing, it becomes apparent from reviewing the literature that there is very little standardization with regard to test protocols [9,10,15], making it difficult to generalize results to the clinical setting. Different manufacturers recommend different protocols for use with their equipment. A typical Cybex H protocol for the knee includes five maximal, sequential quadriceps and hamstring repetitions at 1.08 rad/s (60°/second) followed by a 20 repetition, continuous protocol at 4.32 rad/s (240°/second). The manufacturers of the Kin-Corn have promoted an interrupted (a 5-second pause between sequential quadriceps and hamstring muscle actions) protocol in order to more accurately measure human muscle performance. Theoretically, torque production may also be influenced by a mechanical delay related to acceleration factors or by neurophysiological factors such as the stretch-shortening cycle or muscular coactivation. Both mechanical and neuro-physiological factors may be affected by either the continuous or interrupted protocol [12]. Other protocol parameters, including gravity correction methods, preload, rest intervals, visual and verbal feedback, and subject positioning are frequently not considered by clinicians, which may result in data with limited clinical validity.

The purpose of the present study was to examine the effects of continuous and interrupted stroke isokinetic test protocols and test devices on peak torque output of the quadriceps muscle group. In addition, this study sought to establish the reliability of the interrupted stroke protocol for the Cybex and the continuous protocol for the Kin-Corn.

2. METHODOLOGY

2.1. ***Subjects***

Thirty-one healthy, active males (x age 23.0 ± 2.07 years, X wt 78.2 ± 12.2 kg, x ht 177.8 ± 6.45 cm) participated in this study. Each participant signed informed consent documents in accordance with the guidelines established by the institutional Human Investigation Committee. Subjects were excluded from the study if they reported any history of injury to the dominant knee.

2.2. ***Test protocol***

Subjects were assessed for concentric peak torque at 1.08 rad/s on both Cybex II (Lumex Corporation, Ronkonkoma, NY) and Kinetic Communicator (Chattecx Corp., Hixson, TN) (Kin-Corn) isokinetic dynamometers from 90° knee flexion to 0° knee extension in the seated position. Since the Cybex II software (CDRC) was limited in its ability to manipulate rest intervals, the dual-channel strip chart recorder was utilized for data collection. Kin-Corn acceleration ramps were set to medium and low turn points. The Cybex II does not allow for control of minimum and maximum values or acceleration ramps. On both devices the pelvis and thigh were stabilized by straps for all warm-up and test sessions.

The axis of rotation on the mechanical arm of the dynamometer was set approximately 2 cm inferior and 2 cm posterior to the anatomical axis of the knee to compensate for the inferior-posterior movement of the knee joint axis into the seat cushion during exercise [19]. The shin pad and mechanical arm were aligned with and secured to the subject's lower leg approximately 5 cm superior to the medial malleolus. Lever arm length was recorded and reproduced between devices.

2.3. ***Effect of gravity correction***

The Cybex II employs a dynamic method for gravity correction while the Kin-Com uses a static method. Because the influence of different methods of gravity correction on obtained torque measurements is unknown, the data were not corrected for gravitational influences. Although it is well documented that gravitational effects should be accounted for in isokinetic testing, one of the purposes of this study was to compare the devices, thus every attempt was made to eliminate controllable differences between them.

2.4. *Damp and preload*

To initially equate the systems as much as possible, damping to filter torque overshoot was eliminated from the Cybex setup. Preload, because it is not an option available on the Cybex, was eliminated from the Kin-Corn. Then, to determine if Cybex damp and Kin-Corn preload might produce differences in peak torque between the two devices, assessment followed the manufacturer's recommended protocols (Cybex damp set at 2; Kin-Corn preload set at 75N). The 75N preload was established after pilot testing revealed it to be the highest preload level that did not result in a reciprocal delay time during the continuous mode of testing. The order of testing under damp/no damp conditions was counterbalanced.

2.5. *Data collection*

Random selection was used to determine on which device the testing would commence (Cybex or Kin-Corn) as well as which protocol (continuous or interrupted) would be used first. After receiving instructions regarding the test protocol, each subject folded the arms across the chest, was allowed to see the monitor or torque recorder [2], and was given consistent verbal encouragement to maximize effort. Each subject was allowed 5-10 submaximal contractions for familiarization and warm-up [9]. Following the warm-up and 1-minute rest, each subject performed five test repetitions. After a 3-minute rest period, the procedure was repeated for the second protocol during the same test session with damp and preload conditions applied. The entire procedure, including the order of test protocol, was repeated on the second dynamometer at a second test session no later than 48 h after the first session. Protocol C (continuous) consisted of five consecutive, reciprocal quadriceps and hamstring contractions without pause. Protocol I (interrupted) utilized a single stroke in either flexion or extension.

The interrupted protocol began with movement into knee extension followed by movement into knee flexion. Each movement in the interrupted protocol was separated by a 5-second pause. The purpose of the pause was to allow the subject to rest between each effort and minimize the mechanical or neuromuscular influences occurring during the continuous protocol. For the Kin-Corn, movements were repeated until three consistent torque overlays were obtained. On the Cybex, five interrupted cycles were performed. During the Cybex interrupted protocol, the leg and lever arm system was held in full passive extension, the rest interval was timed with a stopwatch, and the command for the subject to pull the leg into flexion was given. As soon as the command was given, the stabilization was removed.

For both instruments, the continuous protocol began with movement into knee extension followed immediately by reciprocal movement into knee flexion without pause. On both the Kin-Corn and Cybex, each subject performed five cycles of reciprocal concentric knee extension and flexion.

2.6. *Test-retest reliability*

Ten subjects were retested using the Kin-Corn interrupted and continuous protocols in both the 75N preload and no preload conditions (four tests) to establish test-retest reliability. Similarly, a second group of subjects was tested on the Cybex for both the continuous and interrupted protocols under conditions of damp and no damp. Seven days separated the first and second tests.

2.7. *Statistical analysis*

Three 2 x 2 within subjects repeated measures analyses of variance (ANOVA) for quadriceps peak torque were performed for (1) device (Cybex, Kin-Corn) x protocol (interrupted, continuous) using manufacturer's recommended settings (preload of 75N, damp setting of 2), (2) Kin-Com protocol (interrupted, continuous) X preload (ON, 75N), and (3) Cybex protocol (interrupted, continuous) x damp (damp 0, damp 2), respectively. The device X protocol ANOVA sought to determine if differences in peak quadriceps torque production existed between devices or protocols. All torque values reported in this study were for gravity uncorrected values in order to gain equivalence between the devices. The protocol X preload and protocol X damp ANOVAs determined if differences existed between protocols and two levels of preload and damp for the Kin-Corn and Cybex, respectively.

Intraclass correlations (2,3) [14] and associated standard errors of measurement (S.E.M.) were calculated for the Kin-Corn interrupted and continuous protocols as well as for the Cybex interrupted and continuous protocols.

3. RESULTS

3.1. *Kin-Corn ANOVA*

The interrupted protocol on the Kin-Corn resulted in higher peak torque values (P 0.05) regardless of the preload used. There was no significant main effect for preload or interaction between preload and protocol type (Table 1).

3.2 *Cybex ANOVA*

The undamped conditions on the Cybex resulted in higher peak torque values than the damp 2 condition. No main effect was found for protocol when measured on the Cybex H. A trend (P 0.077) toward a significant interaction between damp and protocol was exhibited (Table 2).

3.3. *Protocol X device ANOVA*

Although the values for Cybex were the same for both interrupted and continuous protocols, a significant interaction between protocol and device was found ($P = 0.002$). A significant main effect existed for protocol; with the interrupted protocol yielding higher peak torque values ($P = 0.02$). A significant main effect for device revealed that quadriceps peak torque values were higher when measured on the Kin-Corn ($P = 0.035$) (Table 3).

3.4. *Intraclass correlation coefficients and standard error of measurement*

Intraclass correlation coefficients and the corresponding standard error of measurement for quadriceps peak torque across gravity uncorrected, damped, preload conditions of protocol (interrupted and continuous) and device (Kin-Com and Cybex) are reported in Table 4. ICCs ranged from 0.88 to 0.98, indicating a high degree of test-retest reliability for both continuous and interrupted protocols under the test conditions. Measurements obtained on the Cybex demonstrated higher reliability than those obtained on the Kin-Com.

Table 1
Effects of protocol on Kin-Corn assessment of quadriceps muscle group peak torque values (N , m)

Protocol X Preload	Continuous x S.D.	Interrupted x S.D.
Preload (75N)	182.2 ± 35.5	199.1 ± 44.9*
No Preload	181.7 ± 36.7	194.9 ± 44.1*

* Significant protocol main effect with interrupted > continuous; P 5 0.05.

Table 2
Effects of protocol on Cybex assessment of quadriceps muscle group peak torque values (N • m)

Protocol X Damp	Continuous x S.D.	Interrupted X S.D.
Damp (2)	183.3 ± 33.9	181.7 ± 35.0
No damp	185.1 ± 31.7*	189.7 ± 34.5*

*Significant damp main effect with no damp > damp; P s 0.05

Table 3
Effect of assessment device on quadriceps muscle group peak torque values

Protocol x Device	Continuous x SD	Interrupted x SD
Kin Corn (preload)	182.2 ± 35.5'	199.1 ± 44.9*t
Cybex (damp)	183.3 ± 33.9.	181.7 ± 35.0*

*significant protocol main effect with interrupted > continuous; $P = 0.02$.
tsignificant device main effect with Kin-Com > Cybcx; P 0.035.

Table 4
Intraclass correlation coefficients (2,3) and standard error of measurement (in N m) for test-retest reliability of quadriceps peak torque values

Protocol	Kin-Com	Cybex
Interrupted	0.88 (7.52)	0.98 (3.30)
Continuous	0.91 (7.04)	0.92 (8.42)

4. DISCUSSION

4.1. *Protocol*

The primary finding in this study was that the interrupted protocol clearly resulted in higher peak torque values than the continuous protocol for the Kin-Corn as demonstrated by the interaction between device and protocol. Although the actual Cybex value for the continuous protocol was slightly higher than the interrupted (183.3 vs. 181.7 N, m) protocol, the main effect for protocol indicated the interrupted protocol was significantly greater than the continuous protocol. The difference between the protocol types for the Kin-Com could have been so great as to result in a significant interaction although the data do not demonstrate differences in peak torque production between interrupted and continuous protocols for the Cybex. Thus, the Kin-Com is affected by protocol selection, with the interrupted protocol yielding the highest results while the Cybex appears to be unaffected by protocol selection. Although data collection using the continuous protocol may be more time efficient, a number of investigators [6,19,20] have utilized the interrupted stroke protocol.

The interrupted stroke protocol could be postulated to mitigate the effects of muscular coactivation, reflex potentiation, and fatigue on isokinetic torque production. Muscular coactivation, particularly at the ends of movement is necessary for joint stabilization and deceleration, as strong quadriceps action is accompanied by antagonist coactivation. It has been suggested [12] that the influences of antagonist muscle tension in reducing agonist torque production should be considered when evaluating isokinetic data. The interrupted protocol may reduce the influences of muscular coactivation, although the optimal interval between antagonist muscle actions has not been established. It should be noted that the intra-repetition rest interval between each muscle action during the interrupted protocol is variable in the literature, ranging from 1 s [6] to 5 s [19] with no consensus regarding the optimal rest interval to ameriolate the effects of fatigue.

In addition to the effects of fatigue, mode of contraction (concentric and eccentric) and test order (concentric-concentric, concentric-eccentric, eccentric-concentric) may affect the differences observed between the interrupted and continuous stroke protocols. We examined only the differences between interrupted and continuous stroke protocols on the concentric peak torque production of the quadriceps; therefore, the effect of contraction mode on protocol warrants further investigation.

Observed differences between the interrupted and continuous protocols may be due to mechanical factors, including the intra-repetition interval separating knee flexion and knee extension during the interrupted protocol. This intra-repetition interval is in contrast to the inter-repetition interval separating cycles of motion (e.g. the interval between a single repetition of reciprocal knee flexion/extension without a pause between flexion and extension). Reciprocal delay time is the delay occurring between the movements of uninterrupted flexion and extension as the limb changes direction and begins to generate torque in the opposite direction. During the interrupted exercise protocol, the reciprocal delay portion of the interval is eliminated. However, the delay time between the onset of limb movement and torque production occurring at constant velocity remains unchanged. During the continuous protocol, it could be speculated that the delay time caused by limb acceleration and deceleration at the ends of the range of motion may result in less time for torque production, thus depressing peak torque values.

Differences in data collection methods between the Cybex II and Kin-Com II may have introduced some measurement error. Each grid division for the Cybex data represented 8.2 N•m while torque was measured to the nearest N • m by the Kin-Corn software. Although newer isokinetic systems have considerably improved measurement accuracy over the Cybex II, many clinics continue to utilize the older models of the Cybex II with the strip chart recorder used in this study. As a result, useful data for comparisons in this study were limited to peak torque values obtained by the strip chart recorder (SCR). Systematic error may be introduced by the method of reading the SCR, either consistently higher or lower than the true value.

4.2. ***Test device***

A significant difference in quadriceps peak torque existed between the Kin-Com and Cybex when tested using the manufacturer's recommended settings for preload and damp. These findings at 1.08 rad/s are in agreement with those of Greenberger et al. [5], who found significant differences in peak torque production between the Cybex, Biodex and Kin-Corn. However, at 4.32 rad/s they found significant post-hoc differences in peak torque production between the Biodex and the other two isokinetic dynamometers. These findings raise the possibility of the lack of equivalence and measurement consistency when measuring differing muscle groups or assessment of the same muscle group at differing velocities. Our Kin-Corn II is capable of testing at velocities only up to 3.78 rad/s. Thus, a comparison of the two devices at higher velocities was not possible in our study. Moreover, it has been our impression that comparisons of peak torque within a range of 1.08-3.78 rad/s seldom reveals more information.

Although gravity correction results in a more valid reflection of muscular torque generated in the clinical setting, one of the purposes of our research was to compare the isokinetic devices themselves, hence the elimination of gravity correction from torque values obtained on both the Cybex and Kin-Corn. A limitation of our data is that it should not be used for comparison with gravity corrected data either in the clinical setting or with other normative data in the literature that has been gravity corrected. However, for our investigation the elimination of gravity correction was necessary because the Kin-Com utilizes a static measurement procedure while the Cybex utilizes a dynamic procedure. Also, gravity correction is not possible using the Cybex strip chart recorder. Thus, elimination of gravity correction was employed to eliminate as many controllable differences as possible between the two devices.

4.3. *Preload and damp*

Static preload, or threshold force, has been defined as the isometric force applied by the musculature to the load cell to activate the dynamometer and initiate movement. The existence of preload results in increased average torque values without affecting peak torque values [8,10,18]. Several authors [4,8,10] have suggested that preload will decrease the torque oscillations during the transition from the freely-accelerating limb movement to the controlled isokinetic movement.

There is a lack of standardization in the literature regarding the use of preload in the test protocol. Preload values at the knee range from 20N [10], to 50N [8,10,19], to 100N [10], and 25-75% maximum isometric capacity [8,11]. The 75N preload was determined during pilot testing to be the largest possible preload that would not increase the reciprocal delay interval between the reciprocal concentric muscle actions. Preload did not significantly affect quadriceps peak torque values, in agreement with the findings by others [8,10,18] who found no differences in peak torque- for the quadriceps under differing preload conditions.

Although average torque and other whole-curve parameters were not examined in this study, clinicians should be aware that the existence of preload will affect isokinetic test results, particularly whole-curve data [8,18]. Conceivably, the degree of preload could alter average torque production values; the greater the preload imposed, the greater the average torque produced. Clinicians who unwittingly increase preload forces or change other protocol parameters between isokinetic tests might be led to the erroneous conclusion that their subject had increased in strength when, in fact, those changes were due to changes in test protocol. These elements further suggest that test protocols be standardized for clinical use.

Unlike the Kin-Corn, the Cybex II employs a freely-accelerating lever arm. During the free acceleration phase, the limb accelerates until it has achieved the preset angular velocity of the dynamometer. Once the subject achieves the preset velocity, the dynamometer resistance mechanisms are activated and the dynamometer begins to resist motion, decelerating the limb to the preset velocity. This phenomenon is reflected as an artifact known as 'torque overshoot' [13]. The damp mechanism on the Cybex is designed to slow the stylus response of the strip chart recorder (SCR) to yield a more accurate representation of torque produced throughout the range of motion. Peak quadriceps torque values were observed to occur between 60 and 70° knee flexion, consistent with other reports regarding the angle of peak torque occurrence; this suggests that measurements were not made during the early portion of the range of motion subject to influences by torque overshoot. Accordingly, undamped quadriceps peak torque values were greater than damped quadriceps peak torque values (P 0.05).

4.4. *Reliability and measurement precision*

This study demonstrated ICCs greater than 0.88 for quadriceps peak torque measured on both devices (continuous protocol on the Kin-Com, interrupted protocol on the Cybex). The reliability of the other protocols has been established elsewhere [7,9,10]. Although the ICCs were good, the Cybex demonstrated greater reliability for the interrupted protocol than for the continuous protocol, while the reverse was true for the Kin-Corn. The higher reliability coefficients for the Cybex were likely related to the use of the strip chart recorder rather than the computer software as used with the Kin-Corn. The strip chart recorder necessitates estimating to one-half of a grid division, or approximately 4.1 N m. Differences within this range would thus be undetectable during a retest session and may have contributed to higher reliability coefficients for the Cybex rather than for the KinCom.

The standard error of measurements calculated for each of the ICCs were equal between the protocols on the Kin-Corn but higher for the Cybex continuous protocol than for the Cybex interrupted protocol, suggesting equal precision between_ the two protocols on the Kin-Com. Clinicians may use S.E.M. values reported in the literature for making inferences that a true change (rather than a change due to measurement differences) in an athlete's isokinetic force production has occurred only if the same protocol and procedure have been followed on the same device as that reported in the literature.

5. CONCLUSION

The present study provided evidence for the following conclusions: (1) The interrupted stroke protocol resulted in greater quadriceps peak torque for the Kin-Com but not the Cybex; (2) comparisons between test protocols suggest high reliability of measurement on both devices. Clinicians are strongly encouraged to standardize all aspects of test protocol in order to eliminate variability due to protocol differences, regardless of test protocol employed. The interpretation of isokinetic test results should be protocol- and population-specific.

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