METHODOLOGICAL INVESTIGATION

MEDICINE AND SCIENCE IN SPORTS AND EXERCISE
Vol. 14, No. 5, pp. 368-375, 1982

The nature of torque "overshoot" in Cybex isokinetic dynamometry

ALEXANDER A. SAPEGA, JAMES A. NICHOLAS,
DAVID SOKOLOW, and ANTHONY SARANITI

The Institute of Sports Medicine and Athletic Trauma
at Lenox Hill Hospital
130 East 77th St.
New York, NY 10021

ABSTRACT

SAPEGA, ALEXANDER A., JAMES A. NICHOLAS, DAVID SOKOLOW, and ANTHONY SARANTINI. The nature of torque "overshoot" in Cybex isokinetic dynamometry. *Med. Sci. Sports Exercise*, Vol. 14, No. 5, pp. 368-375, 1982. Transient peaks or "spikes" frequently appear in the initial segments of torque curves recorded with the Cybex isokinetic dynamometer. The purpose of this investigation was to determine whether these spikes represent artifact or transient initial surges of true muscular force output. Cinematographic analysis using both inert weights and a human subject as the source of torque input to the Cybex revealed that the dynamometer's input lever initially exceeded the pre-set angular velocity by an amount ranging from 11% (inert weight; pre-set Cybex velocity = 180°/s) to 200% (human hip abduction; pre-set velocity = 30°/s). The majority of this "overspeeding" occurred in the latter part of the free acceleration period, prior to the engagement of the dynamometer's resistance mechanism. The remainder occurred in the initial part of the elastic loading phase, just after resistance had engaged. A sharp deceleration of the overspeeding lever and the affixed weight or limb then followed in response to the dynamometer's continuing build-up of resistance. Simultaneous with this deceleration, a prominent torque spike was recorded that superseded the correct (mechanical equilibrium) torque value. Within our error of measurement, the deceleration observed in the film quantitatively accounted for all of the "overshoot" torque, i.e., that amount of the spike that exceeded the correct value. It was concluded that such prominent, initial torque spikes represent inertial forces and should not be confused with true muscular tension development.

MUSCLE STRENGTH TESTING, ISOKINETIC DYNAMOMETER, BIOMECHANICS

The Cybex isokinetic dynamometer has come into widespread use for the measurement of human in vivo muscular performance in the fields of orthopaedics, rehabilitation medicine, physical therapy, and exercise physiology. To facilitate valid interpretation and comparison of the isokinetic data presently being published, standardized testing techniques and accurate methods of reading the Cybex's graphic torque records should be adopted. It is intended that this paper contribute toward this goal by defining the nature and etiology of an "overshoot" artifact that frequently appears in the Cybex's graphically recorded torque measurements.

As shown in the strip-chart records reproduced in Figure 1, what we refer to as "overshoot torque" typically appears as a prominent, initial spike in the subject's torque output curve, which may be followed by a short series of progressively diminishing secondary oscillations. At a "damping" setting of zero on the Cybex recorder, we have observed these spikes in torque curves from a wide variety of upper and lower extremity tests. They are most prominent when testing proximal joint motions in which a larger moving limb mass and a longer lever are involved. We seriously questioned the nature of these high initial spikes when we found that, for many subjects, the spike torque levels generated in dynamic tests were higher than the maximum isometric torque output capability at the same angular joint position. The strip-chart recorder was ruled out as the source of these spikes when we found that they were unchanged in oscilloscope tracings of the Cybex's torque signal.

In an isokinetic study of muscle force-velocity relationships, Perrine and Edgerton (2), commenting on these initial torque oscillations in general, attributed them to the partly elastic nature of the muscle-instrument system. However, a search of the literature did not yield any studies specifically investigating or documenting the nature of these phenomena. The questions that we hoped to an-

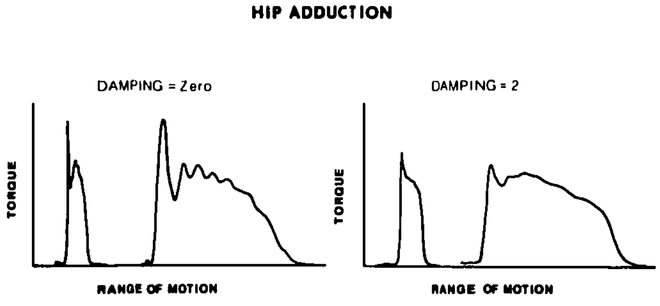


Figure 1—Cybex strip-chart records illustrating examples of "overshoot" torque spikes at damping settings of 0 and 2 on the Cybex recorder. The left-hand curve of each pair was recorded at a slow (5 mm/s) paper speed; the right-hand curve of each pair was recorded at a fast (25 mm/s) paper speed.

Submitted for publication November, 1980.
Accepted for publication May, 1982.

swer in this investigation were the following:

1) Are these initial torque oscillations caused by intermittent surges of true muscular force output, or are they artifacts of some kind?
2) If muscular force is not responsible for such torque spikes, what do they actually represent, what is the mechanism by which they are produced, and how should they be dealt with?

METHODS

An instrumentation and recording system was devised (Figure 2) to enable us to simultaneously measure: 1) the absolute displacement-over-time of the Cybex's input arm at the point of distal force application (the summation of lever arm rotation plus any displacement associated with deformation of the input lever, dynamometer stand, etc.), and 2) the input torque registered by the load cell within the dynamometer.

A vertically and radially calibrated backdrop was placed immediately behind the vertical plane of the input lever's rotational path. A high-speed motion picture camera recorded the time and motion parameters of the Cybex in action. The maximum error in determining angular position of the Cybex input lever from the film was 0.3°, or less than 4 mm linear arc distance at the distal end of the 76.2-cm lever where system displacement was measured. Film speed was 42⅔ frames/s, giving a time interval between frames of 0.0234 s.

To provide simultaneous measurement of torque and input arm displacement, an oscilloscope tracing of the torque signal from the dynamometer was recorded on the film in real-time synchrony with lever arm motion. This was accomplished by focusing a closed-circuit video camera directly on the oscilloscope screen, allowing for online display of calibrated torque traces (enlarged to scale by a factor of 10) on a full-size video monitor situated within the viewing field of the high-speed camera.

Prior to all filmed test runs, the Cybex's load cell was checked for accuracy in both static and dynamic torque measurement and found to be within ±1% at full scale (488 Nm). Error was typically less than 1.4 Nm in the 65-200 Nm range, which encompassed the torque values generated in our filmed test runs.

Two testing modes were employed in this investigation. For our initial tests inert weights were secured to the end of the Cybex's input lever (Figure 2, left inset). In the final test runs a human subject was filmed while performing maximum effort hip abduction contractions (Figure 2, right inset). A hip movement was chosen because of the characteristically large initial torque spikes produced (Figure 1). This increased our relative accuracy by maximizing the quantity of overshoot torque generated in relation to

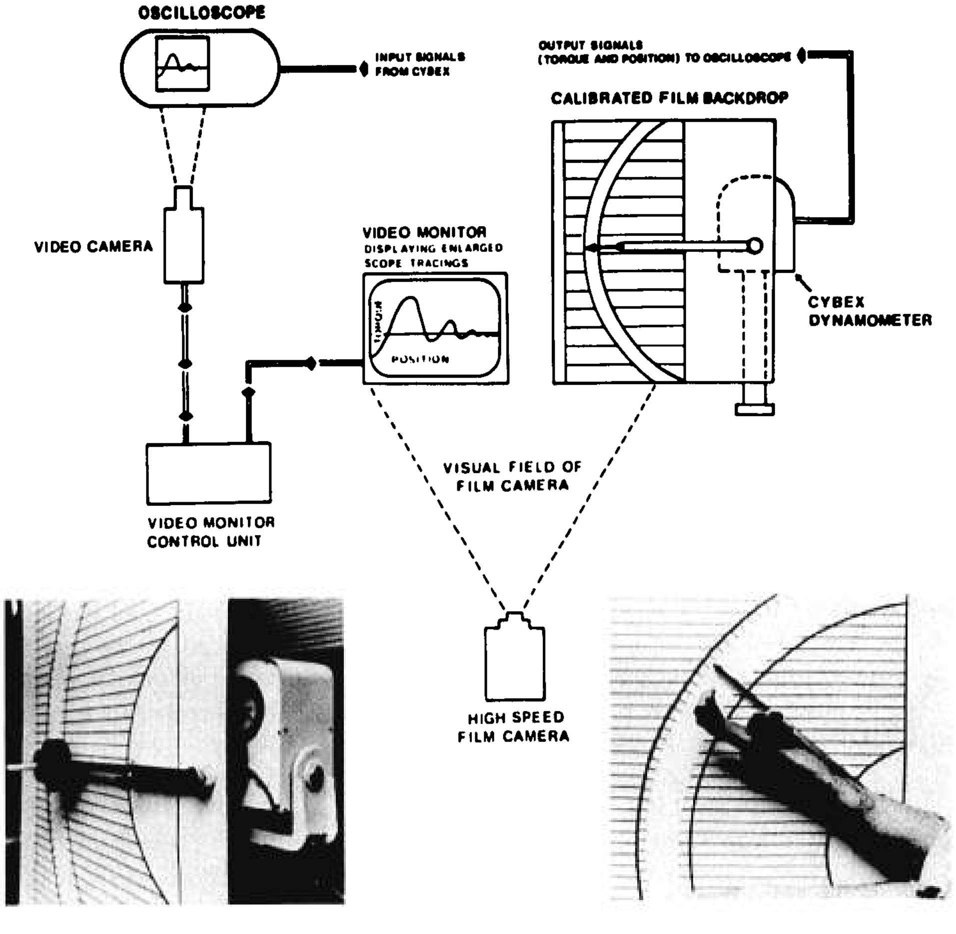


Figure 2—Configuration of instrumentation and recording system. Insets at lower left and right show positioning of weights and human subject in filmed tests.

our inherent error of measurement.

Overshoot generation with inert weights

Metal weights, having a total mass of 9.06 kg, were securely fastened to the distal end of the Cybex's input lever. When the lever was locked statically in the horizontal position, the weights and the lever itself produced 75.9 Nm of torque as measured by the Cybex. Repeated measurements at various times were all within 0.5% of this figure. With respect to all subsequent gravitational torque measurements and dynamic inertial torque calculations, this mass system was equivalent to, and mathematically treated as, 10.16 kg of mass with its center traversing an arc at the end of a weightless 76.2 cm lever arm ($10.16 \text{ kg} \times 9.8 \text{ N/kg} \times 0.762 \text{ m} = 75.9 \text{ Nm}$ gravitational torque at the horizontal position).

Before each filmed test run, a dynamic "reference" torque curve (free from all torque spikes) was generated and stored on the oscilloscope screen. This was accomplished by manually lifting the lever arm to a near-vertical position, setting the Cybex's speed control to 18°/s, and then gradually releasing the input arm, thereby allowing a smooth uptake of force by the dynamometer. The oscilloscope had been placed in X-Y plot storage mode where the X-axis displayed angular (electrogoniometer) position and the Y-axis represented torque. As the weights were steadily lowered by the dynamometer, a smooth torque curve was inscribed across the oscilloscope screen.

For the filmed test runs the Cybex's speed control was first set at 30°/s. An oscilloscope trace containing multiple torque spikes was generated by suddenly releasing the lever and affixed weights from a position 10° above the horizontal. Care was taken not to impart any momentum to the weights in the process of releasing them. The weight-lever system fell with gravity as a freely swinging pendulum until the dynamometer's resistance engaged as the lever arm approached the horizontal position. At this time the first of a series of progressively decreasing torque spikes appeared on the oscilloscope screen. No electronic "damping" of the torque signal from the dynamometer was employed. The oscillating torque curve was superimposed upon the reference curve stored on the screen. Positional axis calibration was identical for both curves. The high-speed camera was activated a few seconds prior to the release of the input arm.

This entire process was then repeated with the Cybex's speed control set at 180°/s. The only change in procedure from the slow-speed test run was that the lever arm had to be released from a higher position (25° above the horizontal) in order to generate a torque tracing near the horizontal position where the camera's parallax error was zero.

The film record of each test run was analyzed with a single-frame, stop-action motion analyzer. For each frame the position of the leading edge of the evolving torque tracing on the video monitor and the angular position of the pointer affixed to the lever arm were traced onto 2×2 m screens and assigned the appropriate quantitative value from the calibrated torque and angular position measurement scales that had been incorporated in the film record.

For each frame the linear arc position (p) of the distal end of the input lever was calculated from its angular position. The equations used in the film analysis are as follows: linear displacement $(d) = \Delta p$; mean velocity $(\bar{v}) = d/t$; and mean acceleration $(\bar{a}) = \Delta\bar{v}/t$. Although we have presented our calculations in linear terms for ease of understanding, it should be noted that overshoot torque is the result of an angular phenomenon. The torque (T) associated with changes in the angular velocity of a rotating mass system is proportional to its angular acceleration $(\pm\alpha)$, the mass (M) of the system, and the square of the distance (r) between the axis of rotation and center of mass of the system, i.e., $T = I \cdot \alpha$, where $I = \Sigma M \cdot r^2$. This accounts for the prominent overshoot spikes observed when testing proximal joint motions such as hip or shoulder abduction-adduction; a high mass (the entire limb) and a long lever (r = the distance between the limb's axis of rotation and its center of mass) are involved. Error in our determinations of acceleration was evaluated by calculating the acceleration of the weights during the free-fall period (prior to engagement of the dynamometer's resistance) as the lever approached the horizontal position. The accelerations calculated from the film were within 5% of actual free-fall acceleration for both the 30°/s and the 180°/s test runs.

Overshoot generation with a human subject (hip abduction)

A special procedure was devised to provide a "reference" torque curve free from any torque oscillations. In our standard isokinetic hip abduction testing procedure (1), the subject assumes a side-lying position on a table. The starting position for the extremity to be tested is at the body midline, and the rotational axis of the input lever is aligned with that of the hip joint. In a modification of this procedure the subject was positioned at the edge of the testing table. This position permitted him to hyperadduct the leg 40° beyond the body midline (below the table's edge) and to extend the starting position by that amount. When the subject initiated a maximal hip abduction contraction (pre-set velocity = 30°/s) from the hyperadducted starting position, all torque oscillations had subsided by the time the limb reached that point in the range of motion where spikes appeared when using the midline starting position. With the oscilloscope in X-Y plot storage mode the subject performed several maximal hip abduction contractions from the hyperadducted starting position. He was well-motivated, familiar with isokinetic test procedures, and consistently able to produce voluntary maximum torque curves that closely superimposed themselves upon one another. A smooth, composite reference curve of maximum muscular torque output, free of any overshoot spikes, was drawn through these curves on the oscilloscope screen in the portion of the range above the horizontal position. The subject was then filmed while performing a maximal hip abduction contraction from the midline (horizontal) starting position. The film simultaneously recorded limb-lever movement and the oscilloscopic superimposition of a typical "spiked" torque curve over the reference curve in real-time on the video monitor.

Maximal-effort hip abduction was also filmed with the Cybex speed control set at 180°/s. We found it impossible, however, to generate an accurate reference curve at this speed. Even when using the hyperadducted starting position, torque oscillations were present throughout the range of motion.

The methods of data analysis for the hip abduction tests were similar to those described for the tests using inert weights. To obtain a base-line value for the inertial torque calculations, the input arm was locked in the horizontal position while the subject maintained his body in the normal testing position. The subject then relaxed his leg completely, allowing it to hang from the rigid lever. In this condition, 51.5 Nm of torque registered on the dynamometer. This was reproducible to within 2.0% between sequential repetitions of maximal hip abduction. With respect to calculating the inertial torque associated with any acceleration or deceleration of the limb and lever, this mass system was equivalent to, and mathematically treated as, 6.9 kg of mass with its center traversing an arc at the end of a weightless 76.2 cm lever.

RESULTS

Test Run #1: inert weights at 30°/s

The torque curve generated by the falling weight (Cybex pre-set velocity = 30°/s) is shown in Figure 3. Following the release of the Cybex's input arm, the weight-lever system fell through an arc of 4° before the dynamometer's resistance engaged, causing the torque trace on the oscilloscope to rise off of the base line. The highest mean angular velocity reached by the weight-lever system was 77°/s, between frames 4 and 5, exceeding the pre-set velocity by 156%. A sharp deceleration of the system followed, between frames 5 and 10. Speed continued to fluctuate, but began to stabilize about the pre-set value of 30°/s after frame 25, where quantitative film analysis was terminated. The initial deceleration between frames 5 and 10 coincided with the generation of the first overshoot spike. Each period of overshoot corresponded to deceleration of the weight-lever system, while each period of undershoot coincided with system acceleration (see Figure 3 legend).

To determine whether the deceleration documented in the film could quantitatively account for the observed levels of overshoot torque, the torque that the dynamometer would have had to exert to produce the initial deceleration of the system was calculated and compared to the actual torque registered by the dynamometer during the initial overshoot spike. The period of maximum deceleration occupied the interval between frames 6 and 9, coinciding with the period of maximum overshoot production (the shaded mid-portion of the initial torque spike in Figure 3). The mean linear deceleration of the system during this interval was 13.2 m/s². This was calculated as follows:

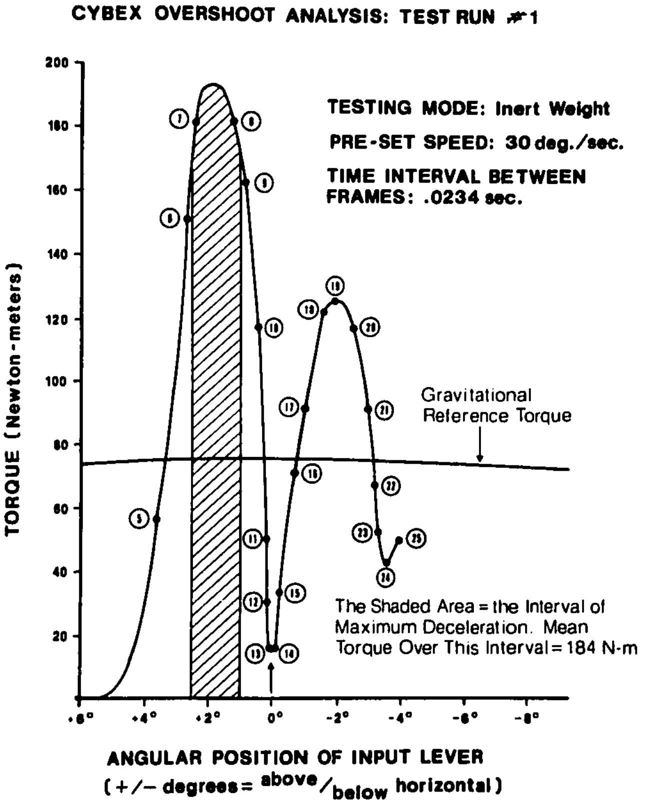


Figure 3—Test Run #1: Generation of overshoot torque with inert weights at an angular velocity of 30°/s. Circled numbers refer to individual film frames. Acceleration occurred between frame intervals 0-5, 10-16, 21-25+. Deceleration occurred between frame intervals 5-10, 16-21.

$$\text{Deceleration} = \Delta\bar{v}/t = [(\bar{v}_{fr\,6\text{-}7}) - (\bar{v}_{fr\,8\text{-}9})]\ /0.0468\ \text{s}.$$

Because $\bar{v}_{6\text{-}7}$ and $\bar{v}_{8\text{-}9}$ represented mean velocity between frame positions, the point in time on the torque trace to which a $\bar{v}$ value was assigned was estimated as midway between frame positions. This determined the boundaries of the shaded area in Figure 3, which corresponded to a deceleration interval of 0.0468 s. It was calculated that the dynamometer would have had to exert a mean resistive torque of (13.2 ÷ 9.8 m/s²) × 75.9 Nm = 102.4 Nm during this interval to produce the amount of deceleration observed in the film. The mean total torque that should have been registered on the oscilloscope over this period, derived by adding the calculated mean torque of deceleration to the mean gravitational reference torque over the same positional range (75.2 Nm), was 178 Nm. The actual mean torque exerted by the dynamometer over this interval was 184 Nm. Thus, within our experimental error of measurement, the predicted inertial torque calculated from the deceleration observed in the film matched the actual overshoot torque.

Test Run #2: inert weights at 180°/s

The torque curve generated by the falling weight (Cybex pre-set velocity = 180°/s) is shown in Figure 4. Kinetic analysis was carried out as described for test run #1. The weight and lever arm fell through an arc of 22° before the dynamometer's resistance engaged. The weight-lever system reached a maximum angular velocity of 200°/s between frames 13 and 14, exceeding the pre-set velocity by 11%. Deceleration of the system followed between frames 14 and 19 (Figure 4, shaded interval) and coincided with the generation of overshoot torque. The mean deceleration of the system during this interval was 6.15 m/s^2. The dynamometer would have had to exert a mean resistive torque of 47.6 Nm during this period to produce the deceleration observed in the film. The predicted total mean torque over the deceleration interval, calculated as the sum of the mean inertial torque of deceleration and the mean gravitational reference torque over the positional range traversed during this interval, was 121 Nm. The actual mean torque exerted by the dynamometer during this interval was 126 Nm.

Test Run #3: human subject at 30°/s

The hip abduction torque traces recorded with the dynamometer's speed control set at 30°/s are shown in Figure 5. The subject raised the lever through an arc of 4° before meeting any resistance. The limb-lever system reached a maximum angular velocity of 90°/s between frames 4 and 5, exceeding the pre-set velocity by 200%. A sharp deceleration of the limb-lever system occurred thereafter, between frames 5 and 9 (shaded interval in Figure 5). Speed continued to fluctuate, but by frame 20 the system had stabilized at the pre-set velocity. At that point, the subject's torque output began to follow closely his own reference torque curve. Between frames 5 and 9, the mean deceleration of the limb-lever system was 9.1 m/s^2. It was calculated that the dynamometer would have had to exert a mean resistive torque of $(9.1\ m/s^2 \div 9.8\ m/s^2) \times 51.5$ Nm = 47.8 Nm during this interval to produce the deceleration observed in the film. The actual mean overshoot torque, that amount in excess of the maximum muscular torque reference curve, during this deceleration interval was 45 Nm.

Test Run #4: human subject at 180°/s

The 180°/s hip abduction torque tracing is shown in Figure 6. Because we were unable to generate an accurate muscular reference torque curve at this velocity, we partitioned the subject's total torque into muscular torque versus inertial decelerative torque through calculations based on the time and motion parameters documented in the film record.

The subject raised the Cybex's input lever through an arc of 15° before engaging the dynamometer's resistance. The limb-lever system reached a maximum mean angular velocity of 256°/s between frames 7 and 8, exceeding the pre-set velocity by 42%. Deceleration of the system then occurred in the shaded interval shown in Figure 6. The mean deceleration observed in the shaded interval was

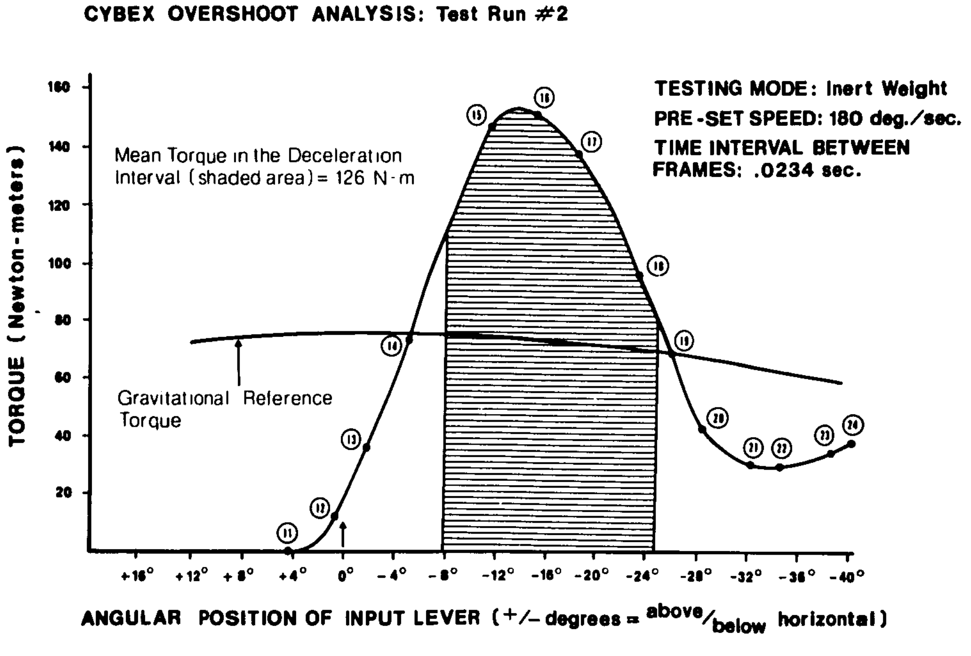


Figure 4—Test Run #2: Generation of overshoot torque with inert weights at an angular velocity of 180°/s. Circled numbers refer to individual film frames.

Figure 5—Test Run #3: Generation of overshoot torque by a human subject (hip abduction) at an angular velocity of 30°/s. Circled numbers refer to individual film frames.

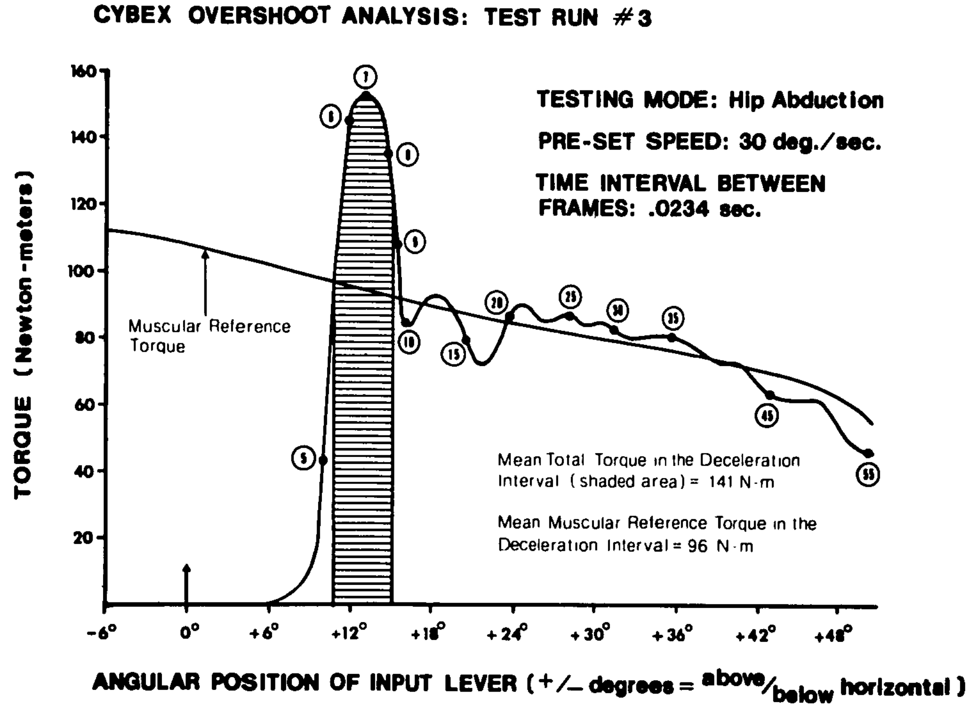
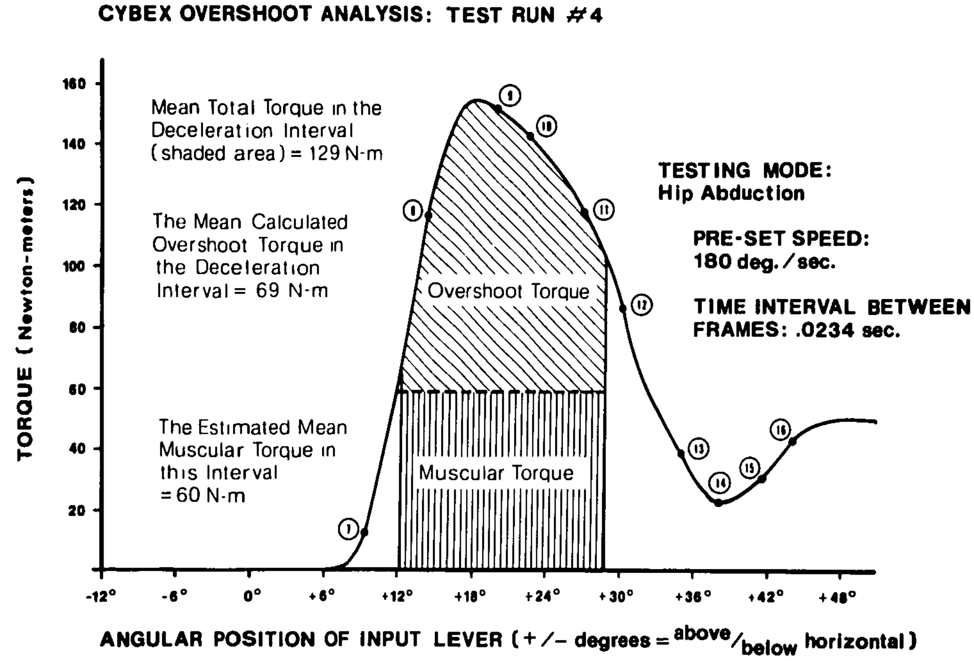


Figure 6—Test Run #4: Generation of overshoot torque by a human subject (hip abduction) at an angular velocity of 180°/s. Circled numbers refer to individual film frames.



13.1 m/s^2. The dynamometer would, therefore, have had to exert a mean decelerative torque of 68.8 Nm during this period. The total mean torque read on the oscilloscope over this interval was 129 Nm. The mean muscular torque was therefore estimated as 60 Nm. Because of the higher contractile velocity, we expected that the calculated value for true muscular torque at 180°/s would be less than the torque measured in the 30°/s muscular reference curve over the same angular positions. This was, in fact, the case. It was the decelerative (overshoot) torque that pushed the 180°/s torque trace above the level of the 30°/s muscular reference torque.

DISCUSSION

In the clinical setting, it is commonly thought that Cybex torque measurements represent purely muscular forces.

In this context, any registered force associated with inertial phenomena rather than the contractile capabilities of the muscle itself constitutes an artifact. Our experiments have documented the presence of inertial artifacts in Cybex torque data generated in a gravitational loading model and in an actual clinical test movement. The dynamometer's torque signal actually represented the net sum of the gravitational or muscular force and any inertial forces present. We were able to show that all (±3-6%) of the overshoot in each analyzed torque spike was accounted for by the torque required to decelerate the weight or limb-lever system. Our results indicated that the large initial overshoot spikes, such as those seen in Figure 1, do not represent transient surges of muscular contractile force but rather the torque required to decelerate an initially overspeeding limb-lever system. The secondary torque oscillations that follow (alternating undershoot-overshoot) are similarly inertial in nature, being associated with alternating periods of acceleration and deceleration, respectively.

The mechanism of the initial overspeeding is worthy of discussion. In our human subject tests at 30°/s and 180°/s, acceleration of the limb prior to the engagement of resistance accounted for 83 and 62%, respectively, of the total amount of overspeeding. These figures take into account the time lag between the actual initiation of resistance and that point when the filmed Cybex torque trace left the base line. This lag was found to be 0.0035 ± 0.0005 s by direct determination. Continued acceleration after the resistance had engaged (during elastic deformation of the rapidly loaded system) accounted for the remaining 17 and 38%. The mechanical properties of the semi-elastic muscle-dynamometer system are important in governing the frequency and rate of resolution of the observed torque oscillations, but as a source of initial overspeeding their contribution was less than that of the excess acceleration that occurred near the end of the dynamometer's initial "free-play" period. However, there does seem to be a trend toward an increasing proportion of post-engagement overspeeding at higher test velocities. Further studies at test velocities above 180°/s may show that elastic loading effects predominate in the high velocity range. It should be noted that the initial overspeeding of the Cybex does not imply that it is defective, but merely that it is subject to some natural limitations in internal and external mechanical coupling and to a certain amount of deformation under loading.

The quantitative similarity between our results with overshoot generation in a hip movement and more commonly used, shorter lever tests such as knee extension can be legitimately questioned. Hip movements tend to produce large overshoot torque spikes due to the long lever and large mass to be decelerated once overspeeding has occurred. Perrine and Edgerton (2), however, have recorded prominent initial overshoot spikes in knee extension torque curves as well. We have observed that when torque signal damping is eliminated, conspicuous overshoot spikes can be found in the torque records of a wide variety of both upper and lower body tests. Although quantitatively smaller, the overshoot torque spikes produced in other test movements are most likely caused by the same inertial phenomena documented in our hip abduction tests.

Implications for Cybex Testing

Torque overshoot is most likely to cause misinterpretation of an isokinetic test record if "peak torque" is used as the measure of strength. A large initial overshoot spike will often be the peak point in the torque curve. If this peak is interpreted to be the subject's maximum muscular force output, it will artifactually inflate the muscular force output data as well as alter inter-extremity strength ratios, reciprocal muscle group strength ratios, etc.

One way we have attempted to deal with overshoot is to eliminate all electronic damping of the torque signal. We have observed that without this smoothing of the torque curves, the point at which torque oscillations subside can be more readily identified. Artifact-free data can be sampled in the portion of the range following the resolution of the torque oscillations. This technique was first reported by Perrine and Edgerton (2), who stated that they were able to obtain oscillation-free data from the latter portion of knee extension torque curves at movement speeds up to 288°/s. This technique, however, is not effective for all test movements when high-test velocities are employed. Our results showed that in hip abduction at 180°/s, the torque oscillations did not subside early enough to permit accurate data collection, even when 40° was added to the range of motion. Further studies are needed to evaluate the effectiveness of this technique with other test movements.

We have also attempted to deal with overshoot spikes by actively using the damping (variable resistance-capacitance) circuit in the Cybex recorder. In the lower range of test velocities, an overshoot spike is typically a sharp waveform with an effective frequency far higher than that of the overall muscle torque curve in which it appears (see Figures 2 and 5). This makes overshoot artifacts potential targets for selective electronic suppression. In our experience, a damping setting of 2 on the Cybex II recorder largely suppresses the initial overshoot spike and any secondary oscillations in all but a few test movements (generally hip and shoulder tests). Increasing the damping beyond a setting of 2 in an attempt to suppress any remaining overshoot has not provided an acceptable solution because this suppresses grossly appreciable quantities of true muscular torque in addition to the overshoot and thus simply substitutes one artifact for another.

Even a damping of 2 affects the muscular torque curve to a small extent, but for our routine clinical tests in the lower velocity range, this artifactual influence has not been a problem. In more rigorous laboratory testing situations where absolute physical quantities are required for proper data analysis, damping must be eliminated and the previously described technique should be utilized for obtaining artifact-free data.

At high test velocities, the use of damping becomes more complex. As test velocity increases, the primary overshoot artifact is spread over a relatively greater portion of the torque curve (see Figures 4 and 6). This causes the frequency of the artifact waveform and muscular torque curve to approach each other, reducing the ability of the damping circuit to suppress the overshoot selectively. This becomes a major problem in high-speed testing of the hip musculature due to the large inertial artifacts produced and the relatively short range of motion. The damping circuit of the Cybex recorder has limited, if any, value when testing the hip musculature at higher test velocities. This is illustrated in Figure 7. A hip abduction torque curve recorded at a damping of 2 has been superimposed on the torque curve from Figure 6, which was recorded without any damping. These curves were generated by successive maximal efforts from the same subject at the same pre-set velocity through the same range of motion. The subject had demonstrated great proficiency in performing reproducible, maximum voluntary contractions, and the difference between the two curves represents the presence vs absence of torque signal damping. In the undamped curve, the artifactual inertial torque and the true muscular torque have largely merged with each other, which should preclude selective suppression of inertial artifact by torque signal damping. Examination of the damped torque curve verifies this as it has simply undergone a non-specific overall flattening and a significant phase shift back in time. For many testing purposes, this would be considered an unacceptable artifact in itself. The damped curve in this case does lie within the general region where the mean level of true muscular torque was calculated to be (Figure 6), but how could one be sure that even this gross correction would be consistent from subject to subject and at different velocities? These results are clear for the hip abduction movement tested in this study. However, conclusions regarding the use of damping for the correction of overshoot artifacts generated at high-test velocities in other test movements, particularly those that employ shorter lever arms, must await further studies.

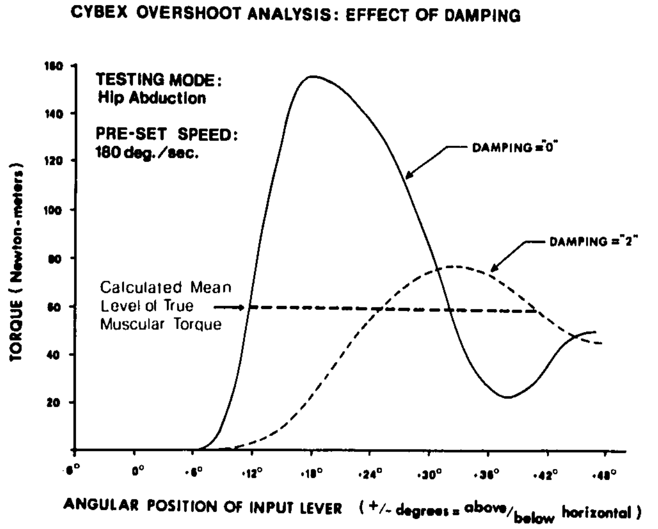


Figure 7—The effect of electronic damping on hip abduction torque curves recorded at a pre-set angular velocity of 180°/s.

CONCLUSIONS

The prominent initial torque spikes and secondary oscillations that often appear in Cybex torque records do not represent intermittent surges of muscular contractile force, but rather the forces associated with the initial deceleration and subsequent velocity fluctuations of an initially overspeeding limb-lever system. The artifactually high torque peaks produced have been termed "overshoot," and the troughs in between "undershoot." They are associated with system deceleration and acceleration, respectively.

When "peak torque" is being used as the measure of strength in Cybex testing, care must be taken not to confuse a large initial overshoot spike with the true peak muscular torque output.

Eliminating all torque signal damping by the Cybex recorder and only sampling data beyond that point in the torque curve where the initial oscillations have subsided is one technique that has been employed to obtain artifact-free data. Maximizing the range of limb motion will generally increase the artifact-free portion of the torque curve.

The damping circuit in the Cybex recorder is capable of suppressing overshoot artifacts, but it can also suppress the muscular torque output signal as well. Care should be taken not to use damping settings that introduce more artifact than they eliminate. Damping should not be used when absolute torque values are required. Investigators using the Cybex should cite the damping setting used in recording their data when reporting their results. Further investigation into the accuracy of overshoot correction by torque signal damping is needed, particularly in high-speed testing.

Present address for Alexander Sapega: 4815 Springfield Avenue, Philadelphia, PA 19143.

James A. Nicholas is a Fellow of the American College of Sports Medicine.

REFERENCES

1. NICHOLAS, J.A., A.M. STRIZAK, and G. VERAS. A study of thigh muscle weakness in different pathological states of the lower extremity. *Am. J. Sports Med.* 4:241-248, 1976.
2. PERRINE, J.J. and V.R. EDGERTON. Muscle force-velocity and power velocity relationships under isokinetic loading. *Med. Sci. Sports* 10:159-166, 1978.