Effect of Instructions on Isokinetic Trunk Strength Testing Variability, Reliability, Absolute Value, and Predictive Validity

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Although isokinetic strength testing has been in use for more than two decades, and numerous studies have addressed isokinetic performance of the lumbar spine, the effect of instructions on isokinetic trunk strength has not been studied. In a sample of 30 healthy women, this study examined the effect of "high-demand" instructions on lumbar strength performance. High-demand instructions were found to have a substantial positive effect on performance variability, reliability, absolute magnitude, and validity. Under these conditions, isokinetic trunk strength was found to be predictive of performance in a frequent lifting–lowering task. [Key words: isokinetic strength, lifting capacity, instructions]

The standardization of evaluation protocols is an important underpinning for the use of performance tests with the lumbar spine. One aspect of this standardization relies on the use of instruction sets that are consistent from time to time and between evaluators. Without uniform instructions, it is not possible to know to what degree the evaluee's performance was related to spurious motivational or cautionary factors injected into the evaluation by the evaluator. As a consequence, both the reliability and validity of a maximum performance test is put in jeopardy. This is such a well accepted tenet that it has been formally adopted as a standard of practice in health care. Standards published by the American Psychological Association[2] emphasize the importance of clear and precise instructions in achieving reliable test results. More recently, the American Physical Therapy Association in its *Standards for Tests and Measurements in Physical Therapy*[16] recommends that primary, secondary, and tertiary purveyors of tests must provide specific instructions to the person being tested. Instructions are to be made available by the primary purveyor in an examiner's manual, and thoroughly described by secondary purveyors in scholarly works.

Beyond the issue of uniformity, however, is the issue of the instructions themselves. That is, what type of instructions produce the *best* results? Is there some strategy that will optimize the reliability of maximum performance testing of the spine? Is there a strategy that will optimize the validity of a maximum performance test of the lumbar spine so that performance on the test can predict performance in work tasks?

Relevant Research

Test Instructions

The importance of uniform instructions is readily apparent. Kroemer and Howard[9] studied the effects of different instructions on 24 male subjects tested for static strength in two different positions. The first position involved pushing against a wall with a built-in force plate in a forward-leaning standing posture. In the second position, the subjects pushed against the same wall with only one outstretched arm while the other side was laterally braced against a parallel wall. This second position involved a smaller muscle mass for force generation, but better body stabilization. The three instruction sets given were: 1) "Hold"—"Exert and hold your maximal force for five seconds, then release," 2) "Increase"—"Apply gradually increasing force until you reach your maximum, then release," and 3) "Jerk"—"Apply your maximum force suddenly twice." In each of the two positions, the different instructions yielded significantly different strength results. The measurements obtained in the second position also were significantly different from one another, but not in the same order as the first position. These differences in results further emphasize the importance of explicit instruction sets and the need to report these with experimental data. A subject's willingness to put forth his full muscular strength capabilities was thought by Caldwell and coworkers[1] to be significantly affected by instructions. These authors presented guidelines that emphasize the importance of clear and explicit instructions, avoiding exhortation, for standard-

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izing tests of muscle strength. These have been referenced in numerous subsequent studies, and currently are in widespread use. In a more recent study, Gamberale[3] found large differences in results among subjects when instructions were not consistent. In a psychophysical strength test in which subjects were allowed to adjust the weight in a box according to various lift–lower frequencies, large discrepancies were found between groups tested by two different examiners. It was later determined that one of the examiners reminded the subjects throughout testing that the subject was free to adjust the load in the box, whereas the other did not. The group that was reminded produced greater maximal acceptable workloads than subjects who were not reminded.

Isokinetic Testing

The isokinetic concept was introduced by Hislop and Perrine[5] and Thistle et al.[18] The term refers to a dynamic type of muscle contraction performed at a constant velocity regardless of the force generated by the muscles. As muscular output increases, there is an equal increase in resistance from the machine, so that no acceleration is allowed. This mode of testing is in widespread use. However, isokinetic performance has not been widely accepted as a valid indicator of "real world" functional work capacity. The argument is that isokinetic movements are not truly functional, since people do not move at constant velocities.

Reliability of Isokinetic Test Performance

Performance tests that demand maximum strength or energy output place the evaluee at potential risk of injury. Self-protective measures are used by evaluees to limit performance within a level that is perceived by the evaluee (on a conscious or unconscious basis) to be safe. As a consequence, the process of testing maximum effort is limited by the evaluee's perception of how much energy or force can be put forth without causing an injury. It is generally accepted that these limits are idiosyncratic, varying from evaluee to evaluee, although there may be variables (such as gender) that effect performance in a systematic manner. Isokinetic performance reliability with lumbar spine testing has been found by Rose et al[15] to have gender-specific features. These researchers studied the reliability of an isokinetic device to test lumbar flexion and extension with a 1-week and 3-week retest interval. Testing was performed at 60°, 120°, and 180° per second with 10 repetitions at each velocity. Men and women were analyzed separately. These researchers found acceptable reliability for men in flexion work at all velocities, but for the women only with flexion work at 180° per second. Reliability was found for men with extension work at 60° and 120° per second, and for women at 120° and 180° per second. The instructions used in this study were not described. There is also no indication that the instructions that were provided to the subjects were uniform within or between sexes. The test–retest reliability of isokinetic trunk strength testing was examined by Smith and colleagues.[17] These researchers found that reliability coefficients for a small set of subjects in a 7-day to 14-day retest ranged from $r = 0.74$ to $r = 0.96$ for trunk extension and from $r = 0.76$ to $r = 0.77$ for trunk flexion. The effect of fear or test anxiety on the reliability of trunk strength testing is suggested by the results of a study conducted by Mayer and coworkers.[14] These researchers found that spinal surgery patients demonstrated substantial deficits in lumbar motion, trunk strength, and lifting capacity when compared with normal subjects without regard to length of disability or the subjects' self-report of pain and disability. Using the Progressive Isoinertial Lifting Evaluation (PILE) procedure in a lift from floor to waist level and a test of isokinetic lifting capability, surgical subjects demonstrated substantial decrements in function when compared to normal subjects. However, the decrements were greater with the PILE than with the isokinetic test. This greater decrement was variously considered potentially attributable to a greater endurance factor found in the PILE test or potentially, a greater fear of injury found in the PILE test.

Validity of Isokinetic Performance

Jacobs et al[7] studied the relationship between isokinetic lifting and performance on both a crate lift and a weight stack lift. Using a single maximum voluntary lift on an isokinetic dynamometer, they found high correlations with progressive lifting tasks with both the crate ($r = 0.96$) and the weight stack ($r = 0.97$) from the floor to a table top at 1.3 m from the floor. Isokinetic tests performance was compared at 0.024, 0.073, and 0.110 meters per second. All correlations between the isokinetic lift test and the performance on the crate lift or the weight stack lift exceeded $r = 0.94$, without regard to the velocity of the isokinetic test within the range tested.

■ Hypotheses

The current study was designed to address these hypotheses:

1. A high-demand uniform instruction set will decrease the variability of performance compared with a uniform instruction set that directs the subject to put forth consistent effort.
2. A high-demand uniform instruction set will increase peak torque production compared with a uniform instruction set that directs the subject to put forth consistent effort.
3. The relationship between performance on a trunk testing device and performance on a test of lifting capacity will be greatest with a high-demand uniform instruction set.

■ Methods

This study developed two separate uniform instruction sets, one of which instructed the subject to put forth high effort (UIS1),

Table 1. Demographic Data: 30 Healthy Female Subjects

	UIS High (SD)	UIS Consistent (SD)
Age (yr)	28.93 (8.02)	30.67 (5.92)
Height (inches)	65.27 (2.25)	65.73 (2.84)
Weight (lb)	130.40 (13.19)	133.13 (21.63)
Maximum lift low (lb)	44.33 (14.50)	40.00 (15.58)
Maximum lift high (lb)	36.67 (11.90)	37.00 (13.99)

and another that instructed the subject to put forth consistent effort (UIS2). The uniform instruction sets were used in an isokinetic back test of healthy normal women (n = 30). After appropriate cardiovascular, musculoskeletal, and general health screening, demographic data were collected. Subjects were randomly assigned to one of two instruction set groups. Subjects were tested in erect standing posture on the Lido Passive Back Machine (Lido, Luredan Biomedical, West Sacramento, CA) at 30°, 60°, 90°, 120°, and 180° per second. Subjects were tested over a uniform 85° of arc. Each subject received four practice trials and four test trials at each velocity. Data were collected for lumbar flexion and extension separately for each subject's peak torque in the gravity-compensated mode. Additionally, as a measure of reliability, each subject's coefficient of variation for each set of four trials was calculated by the testing device and recorded for later analysis. Two evaluators were used, assigned randomly. Evaluator's instructions were audiotape-recorded to insure uniformity within each instruction set and between evaluators. After a 30-minute rest period, each subject underwent testing of frequent lift capacity on the progressive lifting capacity (PLC, Epic Inc., Santa Ana, CA) test. The PLC involves lifting and lowering a progressively increasing weighted crate from the floor to a 30-inch-high shelf, and from a 30-inch-high shelf to a 48-inch-high shelf 4 times consecutively every 30 seconds until a perceived maximum is reached.

The independent variables were uniform instruction set (two levels) and velocity (five levels). Dependent variables included:

1. Coefficient of variation based on the mean of each data point in the force curve of four trials at each velocity divided by the standard deviation of each set of data points. Data were collected at 100 Hz.
2. Isokinetic peak torque, which is given by the Lido in terms of foot-pounds of torque.
3. Frequent maximum lift–lower, which is the maximum that each subject reported she was able to lift "4 times per minute, 8 to 12 times per day" as consequence of performance in the PLC.

■ Results

With regard to demographic variables, unpaired *t* tests for age, height, weight, and the progressive lifting capacity test maximum lift separately over the lower range and the upper range demonstrated no significant differences between the two Uniform Instruction Set groups. Descriptive data for each variable are presented in Table 1.

Effect of Instruction Set on Response Variability

Table 2. Mean Percent Coefficient of Variation: Peak Torque Flexion

	UIS High (SD)	UIS Consistent (SD)
30°/sec	5.73 (1.75)	6.93 (2.84)
60°/sec	6.67 (1.79)	9.47 (4.32)
90°/sec	9.20 (5.03)	14.60 (6.81)
120°/sec	12.53 (4.55)	16.73 (8.61)
180°/sec	13.27 (5.01)	13.60 (7.08)

Repeated measures analyses of variance (2 × 5) of the coefficient of variation datum of each subject's sets of four test trials comparing the instructions with velocity revealed significant effects for instruction set in flexion ($P = 0.0131$) but not in extension ($P = 0.2765$). A significant effect for velocity ($P < 0.001$) was found in both flexion and extension. Interaction effects were nonsignificant. Because the repeated measures design violates the circularity assumption, it is necessary to adjust the degrees of freedom in the *F* test so as to compensate. Accordingly, the Box adjustment[4] was used. This adjustment demonstrates that the repeated measures factor of velocity continues to be statistically significant. Table 2 and Table 3 depict the group-wise mean and standard deviation results for peak torque flexion and peak torque extension, respectively.

Post hoc analyses of the data using the Scheffé method demonstrates that the differences between the groups are significant at 60°, 90°, and 120° per second in flexion. In extension, the group-wise comparison found that there were significant differences at 60° and 90° per second.

Effect of Instruction Set on Torque

Repeated measures analyses of variance (2 × 5) of the peak torque data comparing instruction set with velocity revealed significant effects for instruction set for flexion ($P = 0.035$) and for extension ($P = 0.044$). Significant effects were also found for velocity for both of the measures of isokinetic performance ($P < 0.001$). Interaction effects were nonsignificant. As with the coefficient of variation data presented above, the Box adjustment demonstrates that the repeated measures factor of velocity continues to be statistically significant.

Table 4 and Figure 1 depict the group-wise results for peak torque in flexion. As will be seen, although there is a statistically significant effect for velocity, the changes in torque values do not become apparent at velocities below 120° per second. Both groups are affected similarly. Post hoc Scheffé analyses demonstrate that the difference between the groups are significant at 60°, 90°, 120°, and 180° per second in flexion.

Table 3. Mean Percent Coefficient of Variation: Peak Torque Extension

	UIS High (SD)	UIS Consistent (SD)
30°/sec	9.20 (3.05)	8.87 (2.48)
60°/sec	8.53 (2.47)	11.40 (4.55)
90°/sec	9.93 (3.79)	13.73 (7.86)
120°/sec	15.20 (4.26)	14.47 (4.88)
180°/sec	15.80 (6.88)	16.00 (7.94)

Table 4. Mean Foot-Pounds of Torque: Peak Torque Flexion

	UIS High (SD)	UIS Consistent (SD)
30°/sec	94.80 (21.90)	82.47 (15.73)
60°/sec	98.60 (20.70)	82.20 (19.47)
90°/sec	102.80 (27.06)	78.90 (31.53)
120°/sec	92.27 (40.15)	64.13 (33.43)
180°/sec	49.87 (39.89)	28.13 (14.51)

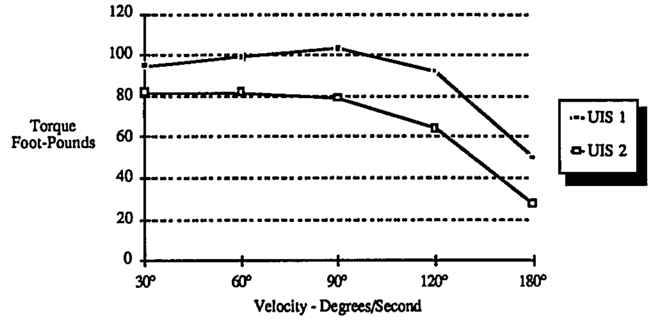

Figure 1. Velocity effects on peak torque in flexion.

Table 5 and Figure 2 depict the velocity effects of peak torque in extension. The group-wise Scheffé post hoc comparisons found significant differences at 60°, 90°, and 120° per second.

Trunk Strength and Lifting Capacity

To measure the relationship between performance on the isokinetic trunk strength device and the progressive lifting capacity test, Pearson product moment correlations were conducted between the maximum psychophysical lift in the high lift and low lift separately on the PLC and the subject's peak torque in flexion and extension at each of five velocities. Tables 6–9 list the resulting correlations.

Table 5. Mean Foot-Pounds of Torque: Peak Torque Extension

	UIS High (SD)	UIS Consistent (SD)
30°/sec	142.27 (40.71)	119.67 (27.47)
60°/sec	145.73 (44.22)	114.07 (37.52)
90°/sec	143.60 (43.33)	106.73 (47.45)
120°/sec	135.60 (54.56)	93.33 (62.17)
180°/sec	79.87 (45.84)	54.13 (48.34)

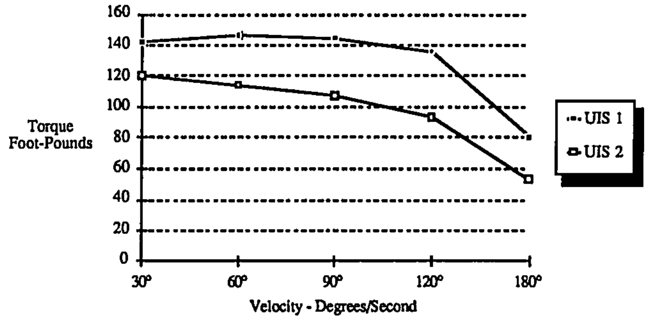

Figure 2. Velocity effects on peak torque in extension.

Table 6. Pearson Product Moment Correlation Coefficients: Peak Torque Flexion and PLC High

	UIS High	UIS Consistent
30°/sec	0.93*	0.36
60°/sec	0.94*	0.28
90°/sec	0.91*	0.29
120°/sec	0.88*	0.40
180°/sec	0.87*	0.40

*Significant at $P < 0.05$.

Table 7. Pearson Product Moment Correlation Coefficients: Peak Torque Extension and PLC High

	UIS High	UIS Consistent
30°/sec	0.68*	0.12
60°/sec	0.78*	0.44
90°/sec	0.77*	0.41
120°/sec	0.71*	0.46
180°/sec	0.82*	0.47

*Significant at $P < 0.05$.

All of the correlations that were calculated in the high-demand instruction set were significant for either the high lift or the low lift, with the exception of the correlation between peak torque extension at 180° per second and the low lift.

In contrast to the correlations found between isokinetic and PLC performance with the high-demand instruction set subjects, none of the correlation coefficients was statistically significant for the consistent-demand group with either the high lift or the low lift.

Table 8. Pearson Product Moment Correlation Coefficients: Peak Torque Flexion and PLC Low

	UIS High	UIS Consistent
30°/sec	0.61*	0.25
60°/sec	0.67*	0.15
90°/sec	0.78*	0.21
120°/sec	0.80*	0.41
180°/sec	0.52*	0.36

*Significant at $P < 0.05$.

Table 9. Pearson Product Moment Correlation Coefficients: Peak Torque Extension and PLC Low

	UIS High	UIS Consistent
30°/sec	0.62*	0.02
60°/sec	0.70*	0.30
90°/sec	0.68*	0.31
120°/sec	0.61*	0.51
180°/sec	0.42	0.47

*Significant at $P < 0.05$.

Table 10. Comparison of Correlation of Isokinetic to PLC High Lift Performance via Z-Score Transformation of Correlation Between UIS High and UIS Consistent

	Flexion	Extension
30°/sec	3.23*	1.72
60°/sec	4.18*	1.44
90°/sec	3.01*	1.43
120°/sec	2.35*	0.96
180°/sec	2.23*	1.60

*Significant at $P < 0.05$.

Comparison of Instruction Effect on Prediction of PLC

To determine whether the effect of instruction set was related to improved correlation between isokinetic and PLC performance to a degree that would be statistically significant, the Fisher Z-score transformation for comparison of correlations[20] was conducted. The results of these analyses are presented in Table 10 and Table 11.

As can be seen in these Tables, the high-demand instruction set appears to have brought about a substantial improvement in the relationship between isokinetic trunk performance and lifting capacity over the high range on the PLC test. However, over the low range, the only statistically significant improvement that was found was with peak torque in flexion at 90° per second.

In summary, the current study found that:

1. Instructions affect the variability of isokinetic trunk performance on an intratask basis.
2. Instructions affect the reliability of isokinetic trunk performance on a test–retest basis.
3. Instructions affect the magnitude of isokinetic trunk performance.
4. Instructions affect the magnitude of isokinetic trunk performance in flexion more than in extension.
5. Instructions affect the magnitude of isokinetic trunk performance in flexion at velocities greater than 30° per second.
6. Instructions affect the magnitude of isokinetic trunk performance in extension at velocities greater than 30° per second and at less than 180° per second.
7. Instructions affect the relationship between isokinetic trunk performance and lifting capacity.
8. With high-demand instructions, isokinetic trunk performance in extension or flexion can be used to predict performance in a frequent lift–lower free weight task.

Table 11. Comparison of Correlation of Isokinetic to PLC Low Lift Performance via Z-Score Transformation of Correlation between UIS High and UIS Consistent

	Flexion	Extension
30°/sec	1.11	1.79
60°/sec	1.61	1.34
90°/sec	2.03*	1.22
120°/sec	1.62	0.37
180°/sec	0.46	0.15

*Significant at $P < 0.05$.

■ Discussion

Most clinicians and researchers agree that instructions given to patients in performance testing are important. However, up to the current study, an optimum instruction set for isokinetic trunk strength testing has not been identified and tested. This study investigated three hypotheses concerning the effects of a high-demand instruction set on isokinetic trunk test performance.

Hypothesis 1: Performance variability. In terms of the effect of instructions on test variability, this hypothesis was supported. If clinicians are to continue to use coefficient of variation cutpoints to discern individuals who are giving full effort from those individuals who are giving less than full effort, the inherent variability in peak test performance further supports the need for the use of proper instructions. The current study demonstrated that coefficient of variation cutpoints may vary considerably, depending on basic test variables. In addition to the use of a high-demand instruction set, it is also necessary to develop individual cutpoints that are based on the velocity and direction of movement.

Hypothesis 2: Peak torque production. One finding that runs somewhat counter to previous studies regards the delay in torque decrement with increased velocity. Although this study found a significant relationship between velocity and torque strength that is in keeping with earlier research, the "fall-off" typically did not occur until the subject reached 120° per second. In contrast, Marras and Mirka[11] found decrements in performance at even slow velocities. These researchers studied the relationship between trunk velocity and torque production around the lumbosacral junction in healthy subjects. Trunk velocity was measured at 10° per second, 20° per second, and 30° per second. This study found that concentric strength decreased by approximately 0.33% of maximum for every degree per second increase in trunk velocity.

Hypothesis 3. Prediction of lifting capacity by isokinetic trunk testing. It is reasonable to expect that trunk strength is related to lifting capacity. The results of this study demonstrate a strong relationship between isokinetic trunk performance and lifting capacity, as long as high-demand instructions are used. A subsequent regression analysis demonstrates this relationship, presented in Table 12 and Figure 3.

Although the small number of subjects in this study limits the usefulness of predicting performance in one task from performance in another, the high degree of relatedness that is evident in these data suggests this as a future application. This would be especially useful in medicolegal evaluations in which it is frequently difficult

Table 12. Beta Coefficients and Confidence Intervals for Regression of Isokinetic Peak Torque (High Demand) on PLC High Lift-Lower

Parameter	Value	SE	Standard Value	t Value	Probability
Intercept	−11.394				
Slope	0.507	0.054	0.933	9.343	1.0000E-4

Confidence Intervals

Parameter	95% Lower	95% Upper	90% Lower	90% Upper
Mean (X,Y)	34.186	39.148	34.633	38.7
Slope	0.39	0.624	0.411	0.603

to know whether or not the evaluee is putting forth maximum effort.

At what velocity should one test trunk performance? If one considers performance variability as measured by the coefficient of variation, 30° per second would appear to appropriate. If one is concerned about maximum torque output, 30°, 60°, or 90° per second would be appropriate. If one is primarily interested in predicting lifting capacity, any velocity between 30° and 120° per second would appear to be appropriate.

It appears that the principal purpose of high-demand instructions may be to attenuate the increased variability that one experiences as isokinetic velocity increases. This increased variability may be due to the increased demand on neuromuscular coordination systems, increased fear and test anxiety, or other intrasubject factors. That it may be an issue of familiarity is suggested by a partial replication of the current study that was conducted subsequently by another group. Totah et al[19] studied the effects of isokinetic task familiarity on peak torque performance and found that although there were no main effects for either velocity or degree of familiarity, there was a significant interaction effect. As velocity increased, torque values declined, although the decline was delayed in the groups that had reported some degree of familiarity with isokinetic testing.

With regard to the effects of instructions, it is useful to consider the strong correlation between isokinetic performance of the high-demand instructions and PLC performance within the context of the analyses of variance for both the coefficient of variation data and the torque data. Recall that the torque analysis found a main effect for instruction at velocities greater than 30° per second. Recall also that the coefficient of variation analyses were similar, although less pronounced. The absolute coefficient of variation increased substantially with increases in velocity and, where there was a statistically demonstrable effect due to instructions, it occurred at velocities greater than 30° per second. No matter the cause, if an isokinetic trunk strength evaluation is conducted with other than a high-demand instruction set, testing at slower velocities would help to control some of the variability, thus improving the reliability and predictive utility of the test results. This is supported by previous research. Kim and Marras[8] found that lifting typically occurs with trunk angle flexion changes on the order of 15° to 30° per second. Marras and Wongsam[13] studied trunk velocity, comparing healthy individuals with individuals who suffer from low-back symptoms. These researchers asked each subject to perform at a self-selected "normal" and "maximum" lifting velocity in unburdened bending in the sagittal plane. The difference between normal and maximum velocity was negligible with low-back pain subjects, but quite pronounced with normal subjects. Mean velocity values in extension ranged from 15° per second for the low-back pain subjects performing at a normal level to 25° per second at a maximum level. This study suggests that an appropriate velocity range for low-back-injured people is much lower, at least in the initial phases of functional restoration, than would be the usual case for similar testing with healthy individuals. Although the range of velocity is somewhat greater, the same difference was found by Hungerford and Johnson,[6] who performed a biomechanical study to develop a means to discriminate correctly between normals and individuals with low-back disorders. These researchers examined trunk velocity and torque in lifting a 30-lb load. Velocity was found to be an important discriminating variable in that normal subjects demonstrated substantially faster trunk extension than abnormal subjects. In this study, the normal subjects performed at 100° per second, whereas the abnormal subjects performed at 63° per second.

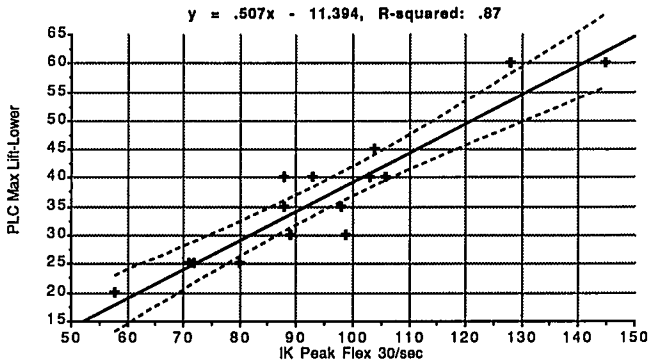

Figure 3. Scattergram with 95% confidence intervals—regression of isokinetic peak torque on PLC high lift-lower.

Conventional clinical wisdom is that appropriate isokinetic trunk strength testing is more safely conducted at velocities that are greater that 30° per second. Simply in terms of duration of load, faster velocities provide less exposure. In fact, the set of normative data provided by the manufacturer of the isokinetic device that was used in the current study[10] includes 20 sets of normative standards, *none* of which were collected at velocities of less than 60° per second. This may be an indication that clinicians' primary focus is on safety. Marras and colleagues[12] studied the correlation between torque and muscle electromyography (EMG) in muscles of the trunk. Both erector spinae activity (as a percentage of maximum activity) and peak torque decreased at velocities greater than 15° per second in a linear fashion. However, activity of these muscles increased when comparing a static strength task with the same task at 15° per second. In contrast, the EMG activity of the latissimus dorsi muscles dependably decreased as velocity increased, although much less abruptly. The torque capacity of the back dependably decreased as velocity increased. The erector spinae muscles increased their activity under slow dynamic conditions as compared with static conditions. As a consequence, under slow lifting conditions, the loading of the spine increases substantially, although there is a loss in demonstrated strength, even at slow velocities. Generally, the correlation between torque and EMG increases substantially at velocities of 30° per second and higher. However, below that velocity there appears to be a differential response comparing the erector spinae and latissimus dorsi muscle groups. Although there appears to be agreement that high-velocity isokinetic testing is not clinically useful, it is clear that studies of the risks involved, if any, in isokinetic testing at 30° per second (or slower) must be undertaken.

Although it would be logical to conclude that high-demand instructions are more dangerous than consistent-demand instructions in that the absolute force values are higher in the high-demand group, this has not been demonstrated. Because it appears to be necessary to use a high-demand instruction set to achieve reliability, any means that would minimize potential risk while retaining the benefits of the instructions would be useful. When using a high-demand instruction set, the authors recommend that the test be undertaken by the evaluee on a voluntary basis with an appropriate orientation to the testing procedure and familiarization with the equipment, including a submaximal test trial. Additionally, the evaluee should be provided with an opportunity to discontinue the test after it has begun. Additional experience with this approach in a population of spinal-impaired subjects is needed to address this issue in depth.

The relationship between isokinetic performance in the high-demand group and PLC performance is impressive. Even more impressive is the comparison of that relationship with the relationship between the consistent-demand group's performances on each test. It appears that this relationship is so strong that it warrants a recommendation to use the high-demand instruction set in an isokinetic trunk strength test protocol as the best means of predicting performance in lifting tasks. Subjects in the high-demand instruction group produced isokinetic performance that had a very high degree of relationship with "real world" performance as exemplified in a free weight-lifting task. Put another way, whenever possible, tests should be selected based on the degree to which extraneous factors that introduce error variance can be controlled. As was demonstrated in the current study, when this occurs with maximum strength tests that are dissimilar but involve many of the same biomechanical linkages, the results of one test can be used as excellent indicators of performance on the other test. The current study demonstrates that, when used properly, this equipment is capable of closely approximating certain aspects of human performance so that it is possible to predict performance in "real world" lifting tasks from performance on isokinetic trunk strength tests.

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