Effect of Preload and Range of Motion on Isokinetic Torque in Women

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Abstract:

The purposes of this study were to compare the effects of two preload settings (0 N, 75 N) and two ranges of motion (5-90° ROM, 25-70° ROM) on torque output of the knee musculature. Twenty females were randomly assessed for isokinetic concentric (CON) and eccentric (ECC) torque of the knee extensor (EXT) and flexor (FLEX) musculature at a velocity of 1.62 rads • s^{-1}. Two four-way ANOVAs (muscle x mode x range of motion x preload) revealed significant differences in average torque between the preload and range of motion conditions (CON EXT: 5-90° ROM, 75 N = 74.3 ± 17.2 Nm; 5-90° ROM, 0 N = 68.3 ± 17.2 Nm; 25-70° ROM, 75 N = 79.0 ± 13.0 Nm; 25-70° ROM, 0 N = 71.5 ± 20.8 Nm) (ECCEXT: 5-90° ROM, 75 N = 85.6 ± 28.6 Nm; 5-90° ROM, 0 N = 82.8 ± 27.8 Nm; 2570° ROM, 75 N = 97.7 ± 23.4 Nm; 25-70° ROM, 0 N = 93.6 ± 26.5 N m) (CON FLEX: 5-90° ROM, 75 N = 43.5 ± 9.2 N m; 5-90° ROM, 0 N = 43.1 ± 5.6 N m; 25- 70° ROM, 75 N = 44.2 ± 8.9 N m; 25-70° ROM, 0 N = 41.2 ± 8.9 N m) (ECCFL EX: 5-90° ROM, 75 N = 56.7 ± 16.3 N m; 5-90° ROM, 0 N = 55.6 ± 17.8 N m; 25-70° ROM, 75 N = 57.3 ± 14.0 N m; 25-70°
ROM, 0 N = 51.8 ± 14.0 N m) ($P < 0.05$). No differences in peak torque values were observed. Based on the findings of this study, preload and range of motion should remain constant between and among subjects if average torque is used as a criterion measure.

Article:

AVERAGE TORQUE, PEAK TORQUE

Isokinetic dynamometry enables assessment of human muscular performance through a full range of motion with the most frequently reported evaluation parameters being peak torque, average power, and total work (7,9,12,14,15,17). Microcomputer interfacing of newer generation isokinetic dynamometers with extensive database capability have provided the clinician with many parameters and options from which to choose. However, these options also provide new sources of variability in assessment and interpretation of isokinetic force/torque. The KinCom (Chattecx Corp., Chattanooga, TN) is one of several isoki netic dynamometers that provide several evaluation parameters including preload and range of motion.

Preload is the amount of force or torque that a subject must produce before the actuator arm will initiate movement. Jensen et al. (8) and Kramer et al. (10) established that preload effects average torque production of the knee extensor musculature. However, the data presented by Jensen et al. (8) and Kramer et al. (10) indicate that the effects of preload settings vary dependent upon the test velocity and mode of contraction. Researchers that utilize the Ki nCom isokinetic dynamometer are utilizing a variety of preload settings (5,7,9,17) for a variety of muscle groups (6, 8,13,19) and at a variety of test velocities (1,6,8,10,18,19).

Based on the findings of Jensen et al. (8) and Kramer et al. (10), and on the fact that several preload levels have been previously utilized and reported in the literature (6,9,10,18), it appears that further research is needed to determine the specificity of the effect of various preloads on isokinetic strength of various muscle groups.

Range of motion is another test parameter that requires clinician specification. Previously, isokinetic assessment performed on the Cybex II isokinetic dynamometer (Lumex, Inc., Ronkonkoma, NY) has always occurred through a full range of motion (7,14,15). However, the KinCom isokinetic dynamometer permits assessment through any portion of a range of motion. The following three studies illustrate variations in methodology with respect to range of motion tested. These studies examined knee extensor torque utilizing the KinCom isokinetic dynamometer and reported data collected from 100 to 30° of knee flexion (12), from 80 to 10° of knee flexion (19), and from 90 to 30° of knee flexion (1). Jensen et al. (8) reported both average and peak torque, whereas Worrell et al. (19) and Baltzopoulos et al. (1) reported only peak torque.

Physiological issues involved with range of motion are potentially related to theories regarding muscle in vitro length-tension relationships. It has been classically established that in vitro skeletal muscle will exhibit an increased amount of tension at the extreme lengthened positions (4,5). This finding has been attributed to the active contractile component of skeletal muscle and to stored elastic energy in a passively stretched skeletal muscle (2). From these studies, it can be further concluded that an optimal length exists at which maximal force or muscular tension will be developed, and that shortening or lengthening away from this ideal point will result in decreased force production of any given muscle group (2,5). Adjusting the range of motion potentially impacts on average torque by adjusting the optimal point at which a muscle is producing an optimal amount of torque. Additionally, if the range of motion is adjusted and does not include the point at which peak torque occurs, peak torque values will be affected. To date, no research has reported the effect of varying ranges of motion on peak and average torque values.

The purpose of this study was to examine the effect of two preload settings and two ranges of motion on peak and average torque output of the knee extensor and flexor musculature. It was hypothesized that preload and range of motion would have no effect on peak torque of the knee extensor and flexor musculature in either mode of contraction. However, it was hypothesized that the lower preload values would result in lower average torque production for the knee extensor and flexor musculature in both modes of contraction. It was also hypothesized that a smaller range of motion would result in greater average torque production for concentric and eccentric knee extension and flexion. Finally, it was hypothesized that the effect of preload and range of motion would be similar for concentric and eccentric knee extension and flexion.

METHODOLOGY

Subjects.

Twenty recreationally active females (age = 20.2 ± 1.01 yr; ht = 169.0 ± 6.8 cm; wt = 60.8 ± 5.5 kg) participated in this study. Written informed consent was given in accordance with institutional human investigation committee guidelines. Subjects were excluded from the study if they reported any history of injury to the right knee.

Test Protocol. Subjects were assessed for dominant extremity (right side in all subjects) isokinetic concentric and eccentric torque of the knee extensor and flexor muscles on a Kinetic Communicator (KinCom) (Chattecx Corp., Chattanooga, TN) at 1.62 rads - s' (90°-s-1). This velocity was chosen because it was employed by Jensen et al. (8) and would thus provide a basis for comparison.

Testing occurred under the following four conditions: 1) 5-90° range of motion, 75 N preload; 2) 5-90° range of motion, 0 N preload; 3) 25-70° range of motion, 75 N preload; and 4) 25-70° range of motion, 0 N preload. Preloads of 0 and 75 N were chosen to complement the preloads reported by Kramer et al. (10) of 20, 50, and 100 N. Ranges of motion of 5-90° and 25-70° were chosen because these arcs were representative of a larger range of motion and smaller range of motion being utilized by both clinicians and researchers (1,10,19).

Testing occurred over two sessions, separated by a minimum of a 2-d interval. Subjects were assessed under two conditions during each session and were randomly assigned to one of four possible testing sequences:

During each test session, subjects rested 30 s between each contraction, and 5 min between each testing condition. Subjects were assessed for knee extensor strength followed by knee flexor strength during each test session. Subjects received no visual or verbal encouragement or feedback during the duration of the study.

Isokinetic Assessment

Knee extensor and flexor assessment. Torque of the knee extensor muscle group was assessed in an upright, seated position utilizing the KinCom back rest attachment. The hip was positioned in approximately 80° of flexion. Torque of the knee flexor muscle group was assessed in the prone position (hip at 0°). Subjects were secured with Velcro straps at the distal thigh, and across the waist. The distal pad was placed slightly proximal to the malleoli. The axis of the dynamometer was aligned with the axis of rotation of the knee.

Gravity correction. All average and peak torque values obtained for each subject were gravity corrected. Gravity correction procedures were performed prior to the onset of data collection. The knee was moved to a position of 30° of flexion, with the subject positioned for knee extension assessment. Subjects were instructed to relax the limb completely during which time the system recorded the amount of force produced by the weight of the limb. This value was replicated and used for assessment of both knee extensor and flexor strength during all testing conditions.

Familiarization procedures. All subjects participated in stretching exercises for the quadriceps and hamstring muscle groups both before and after the testing session. All subjects participated in a familiarization period prior to both isokinetic test sessions. This period consisted of three to five submaximal and one maximal concentric and eccentric contraction for both the knee extensor and flexor muscle groups. Assessment procedures followed a 1-min rest period.

Data collection.

Following a 1-min rest period, subjects performed several maximal concentric and eccentric contractions of the knee extensor muscle group. The data management capabilities of the KinCom's computer software allowed examination of the torque curves produced by the subject as the contractions were executed. Additionally, the torque curve of the most recent contraction is overlayed with the previous torque curve. Therefore, as torque curves were produced and examined, three visually similar torque curves were selected and used for subsequent data analysis. Subjects performed the number of contractions needed to obtain the three reproducible torque curves. This occurred within three to five trials. Following assessment of knee extensor strength, subjects were positioned for assessment of knee flexor strength. Data collection procedures were identical for the knee flexor muscle group.

Test -Retest Reliability

Eight subjects were retested in the condition of 5-90° range of motion (75-N preload) for the purpose of establishing test-retest reliability of the test protocol. Reliability of average and peak torque measures of the knee extensor and flexor musculature was determined. Intraclass correlation coefficients (Type 2,1)(16) were utilized to determine the reliability between the tested and retested measures.

Statistical Analysis

Knee extensor and flexor peak and average torque values were obtained from the KinCom computer software for all four testing conditions. Two four-way analyses of variance were performed: Muscle (extension/ flexion) x Mode (concentric/eccentric) x Range of motion (5-90/25-70) x Preload (0 N/75 N) for the average and peak torque data, respectively. The analysis of variance determined if significant differences existed among the average torque and peak torque values under two different ranges of motion and preloads, for concentric and eccentric knee extensor and flexor torque ($P < 0.05$). Additionally, the interaction between range of motion and preload was examined.

No other interactions were examined for the purposes of this study.

RESULTS

Intraclass correlation coefficients (ICC), their associated standard error of measurement (SEM) values, and *P* values from the repeated measures ANOVA are presented in Table 1. Since the ICC is calculated from a repeated measures ANOVA, *P* values greater than 0.05 indicate no significant difference between test and retest conditions. ICCs ranged from R = 0.48 to R = 0.85.

Average and peak torque values are presented in Table 2. For average torque, analysis of variance revealed significantly greater knee extensor torque values in comparison with knee flexor torque values, greater eccentric torque values than concentric torque values, greater torque measures obtained under the 75 N preload condition than values obtained under the 0 N preload condition, and lesser torque measures obtained through the 5-90° range of motion than those values obtained through the 25-70° range of motion. No significant interaction was noted between range of motion and preload.

TABLE 1. Intraclass correlation coefficients (ICC) and standard error of the measurements (SEM).

Variable	ICC	SEM	P value
Average torque			
Extension			
concentric	0.68	9.90	0.43
eccentric	0.85	14.17	0.22
Flexion	0.60	5.09	0.15
concentric	0.78	6.88	0.97
Peak torque			
Extension	0.81	11.83	0.41
concentric	0.81	23.88	0.08
Flexion			
concentric	0.48	7.27	0.19
eccentric	0.76	9.88	0.82

TABLE 2. Average and peak torque (Nm) values obtained under all testing conditions (mean ± SD).

	Average	Peak Torque
5-90 ROM; 75 N		
Extension		
concentric	74.3 ± 17.2	106.4 ± 27.4
eccentric	85.6 ± 28.6	115.8 ± 41.3
Flexion	43.5 ± 9.2	54.8 ± 11.8
concentric	56.7 ± 16.3	69.9 ± 19.8
5-90 ROM; 0 N		

Extension	68.3± 17.2	99.6 ± 28.6
concentric	82.8± 27.8	112.6 ± 39.4
Flexion	43.1± 5.6	52.4 ± 11.0
concentric	55.617.8	69.9 ± 22.9
25-70 ROM; 75 N		
Extension	79.0± 13.0	98.1 ± 16.7
concentric	97.7± 23.4	125.7 ± 34.7
Flexion	44.2± 8.9	55.6 ± 12.0
concentric	57.314.0	66.9 ± 15.7
25-70 ROM; 0 N		
Extension	71.5± 20.8	92.2 ± 26.3
cncentric eccentric	93.6± 26.5	124.5 ± 38.1
Flexion cncentric	41.2± 8.9	52.3 ± 11.6
eccentric	51.8± 14.0	63.9 ± 17.8

For peak torque, analysis of variance revealed significantly greater knee extensor peak torque values in comparison with knee flexor torque values, and greater eccentric torque than concentric peak torque. No differences were noted between the peak torque values obtained under differing ranges of motion or preloads and no interaction between range of motion and preload was observed.

DISCUSSION

Reliability

The ICCs for the tested variables ranged from R = 0.48 to R = 0.85. These values were comparable to those reported by Kramer et al. (10) and Tredinick and Duncan (18). However, these authors did not report reliability at the velocities utilized in this study. Although some of the ICC values are acceptable, some are indicative of a moderate degree of variability between the test and retest conditions. This is a concern, and further research is needed to ascertain the cause of low reliability coefficients. The low reliability in some of the test conditions in this study is a limitation. A further limitation is the fact that only one of four testing conditions was examined for reliability purposes. The rationale for this decision was to limit the amount of isokinetic testing performed by any one subject. Further study is needed to determine an appropriate protocol for research that would provide high reliability coefficients. Kues et. al (11) published results indicating several days of familiarization may be necessary to obtain reliable isokinetic measurements of the knee extensor musculature. It has become increasingly apparent that reliability under various conditions needs to be assessed so that consistent test protocols may be developed.

Descriptive Data

A plethora of data have been reported regarding the average and peak torque values, generated from both concentric and eccentric contractions, for the knee musculature. In this study, eccentric torque values were consistently greater than concentric torque values. These findings are compatible with the findings of Hageman et al. (6), who reported greater knee extensor torque production when compared with knee flexor torque production. Hageman et al. (6) assessed 12 males and 13 females for concentric and eccentric peak torque at 30 and 180°. s-' utilizing a KinCom isoki netic dynamometer. Testing procedures included a 50-N preload and subjects were tested through 75° range of motion (0-75) for the knee extensors, and 70° range of motion (0-70) for the knee flexors. The findings of H ageman et al . (6) are in agreement with the findings of this study, which produced consistently greater knee extensor average and peak torque production, regardless of the preload or range of motion condition.

Preload

The major findings related to preload were that knee extensor average torque production was significantly greater when the 75 N preload was utilized, whereas no effect on peak torque production was noted. These findings are consistent with Jensen et al. (8) and Kramer et al. (10). Jensen et al. (8) examined the effect of a low preload (50 N) and a high preload (75% of peak isometric torque) condition on concentric and eccentric isokinetic (KinCom) knee extensor peak and average torque in 35 subjects (20 females and 16 males) at a test velocity of 90° • s-1 (1.62 rads • s-'). They reported significantly greater average torque production (approximately 5-6%) under the higher preload condition for both concentric and eccentric contractions. Jensen et al. (8) employed a percentage of maximal isometric torque production as the preload value. This preload will vary among individuals as well as over time within a single individual. Because of the potentially increased source of methodological variability when using a percentage of maximal isometric torque as the preload, common preloads have been investigated.

Kramer et al. (10) examined the effects of a common preload on isokinetic (KinCom) concentric and eccentric peak and average torque production of the dominant knee extensor musculature in 24 female subjects. Velocities of 45° • s-' (0.81 rads • s-') and 135° • s-' (2.43 rads • r') were utilized and preloads were randomly set at 20 N, 50 N, and 100 N. Their findings were consistent with Jensen et al. (8) and support the findings of our study in that the average torque values were greater under the higher preload conditions.

Closer examination of the torque values reported by Kramer et al. (10) reveals that concentric average torque values between the two tested velocities show similar increases in torque for increasing preloads (5-6%). In contrast, the increase in eccentric torque production is not as consistent with small (1%) increases occurring at 45°. s-' (0.81 rads • s-') and larger increases (9%) occurring at 135° • s-' (2.43 rads • s-'). The pattern reported by Kramer et al. (10) is consistent with the observations of this study. Larger increases in torque production were observed for concentric knee extension (8-9%) than for eccentric knee extension (3-4%) (Figs. 1 and 2).

To date, the effect of preload on average and peak torque production of the knee flexor musculature has not been reported. Our study found greater average torque production was observed for the knee flexor musculature in the 75-N preload condition as com- pared with the 0-N preload condition with no differences in peak torque production between the two preload conditions. Concentric and eccentric average torque produced under the 75- N preload condition were 1-2% greater when compared with average torque under the 0-N condition when tested through a greater range of motion (5-90 ROM). However, larger increases were seen in the smaller range of motion (89%) (Figs. 3 and 4).

Dudley et al. (3) examined the effect of voluntary vs involuntary activation (preload) forces on concentric and eccentric knee extensor torques obtained at nine velocities. Their study indicated that neural influences may be responsible for the variability in torques obtained under differing activation conditions. They reported greater effects of activation forces on concentric torque values as compared to eccentric torque values. The study also reported the greatest activation force effect on torque values was obtained when an involuntary isometric contraction was induced via electrical stimulation, further supporting the hypothesis of neural influences.

This hypothesis may be extended to provide a more practical means of examining the relationship of preload and torque production of the knee musculature. Neural influences as well as muscle physiology (fiber type, mode of contraction, and speed of contraction) will determine the type of torque curve produced. The variable effects of preload may be due to the shape of the torque curves produced by different muscle groups under various conditions. It may be hypothesized that the effect of preload is greater when the muscle being assessed is producing a parabolic torque curve. Thus, the findings of our study and Kramer et al. (10) regarding the effects of preload on concentric knee extensor average torque would be consistent in light of the fact that the curves produced are parabolic. Likewise, eccentric knee extension at slower velocities may not produce a parabolic torque curve, and thus the effect of preload is reduced. This hypothesis can be extended to the knee flexor musculature. The torque curves produced by the knee flexors are not parabolic. However, as the range of motion is decreased, the curves appear more parabolic, which would account for the greater effect of preload on average torque production of the knee flexor musculature.

These findings, in conjunction with the findings of Kramer et al. (10), indicate that the effect of preload is specific to the muscle group being assessed, the mode of contraction, the range of motion through which a specific muscle group is being tested, and test velocity. Further research is needed to fully assess the effects of a variety of preloads under different isokinetic testing conditions. Because of the effects of preload on average torque, peak torque should be the measure of choice when comparing isokinetic measures obtained under conditions utilizing differing preloads.

Range of motion. The major finding related to range of motion was that the two tested ranges of motion had no effect on peak torque values, but a significant effect existed for average torque values. The largest increases in average torque production were observed for concentric and eccentric knee extension. When the range of motion was decreased, the average torque production increased (Figs. 1 and 2). The smallest effect was observed for average torque of the knee flexors. Under the 75-N preload condition, the average torque production increased when the range of motion was decreased. In contrast, under the 0-N preload condition, the concentric and eccentric knee flexor average torque values decreased when the range of motion was decreased (Figs. 3 and 4).

The difference in average torque for the muscle groups between the two ranges of motion may be related to the type of torque curve produced by the muscle groups under the differing contraction modes. The concentric knee extension curve is a parabolic curve and the eccentric knee extension curve is an ascending curve. When the range of motion is shortened, the lowest points of a full curve are not present. This would act to increase the average torque value. In contrast, knee flexion curves resemble flat curves, and a shortened range of motion does not eliminate lower points present in a full torque curve.

In summary, our study indicates that peak torque was not significantly affected by changes in preload and range of motion when assessing the knee extensor and flexor musculature and that average torque was affected by the aforementioned variables. Therefore, when assessing isokinetic muscular performance, the range of motion and preload should be held constant. If this is not possible, peak torque measures should be used as the criterion measure.

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