Comparison of N-K Table Offset Angles with the Human Knee Flexor Torque Curve

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Abstract:

The purpose of this study was to dynamically examine various offset angles on the N-K table to determine which offset produces a torque pattern corresponding most closely to the isokinetic torque curve of the knee flexor musculature when tested at 607s. Subjects for the study were five college- age male volunteers (age=21.8±1.8 yrs, ht=181.9±4.3 cm, wt=88.4±12.6 kg). Mean peak isokinetic torque values for the five subjects were measured at 5° increments to represent the human knee flexor torque curve. These were converted to relative mean values by dividing each value by the maximum mean peak torque. Torque curves from four offset angles (90°,110°, 135°, and 160 °) for the N-K table were obtained by using the Kin Com in the passive mode at 207s to push the exercise arm of the N-K table through a range of motion of 0° to 90° while recording torque and angular position. The four torque curves were converted to relative values in a similar manner as for the subjects. Qualitative analysis reveals that the 160° offset angle most closely corresponded to the representative knee flexor isokinetic torque curve, while the 90° offset angle corresponded least. Although these findings would seem to support reconsideration of common clinical practice relative to the use of the N-K table for knee flexor strength development, the 160° offset angle is awkward because it has a tendency to force the user into hyperextension at the beginning phase of motion. As such, practical compromises might include the use of the 110° or 135° offset angle in lieu of the traditionally employed 90° offset angle, or the development of an extension stop that would prevent hyperextension of the knee.

Article:

Strength development is an important aspect of most rehabilitation programs. To optimize strength gains, many clinicians use several forms of training, including isometric, isotonic, and isokinetic exercises. Of these, isotonics might be the most widely employed strength training method. Lamb[6] defines an isotonic exercise as one in which a constant load is moved through a range of motion of the involved joints.

In 1954, Noland and Kuckhoff [9] introduced an innovative isotonic resistance device known as the N-K table which still is used widely today. It was designed to make progressive resistance exercises for the quadriceps and hamstring muscle groups more convenient and efficient. The unique aspect of the N-K table is the adjustable lever arm that holds the weight and is, thus, termed the "resistance arm." This is separate from the "exercise arm," which is the arm that contacts the user. The resistance and exercise arms can be offset from one another at various angles by rotating the interface cam into position, where a pin connects the two arms. As the relationship of the two lever arms is altered, so is the point in the range of motion at which maximum resistance is realized. In terms of biomechanics, maximum resistance is reached when the

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resistance arm is horizontal to the floor.' The question, then, is: "At what offset angle between the resistance and exercise arms does the maximum resistance most closely correspond to the strongest point in the human strength curve?" A thorough understanding of how torque patterns vary at different offset angles and how this relates to the torque curves for the knee flexor musculature is of obvious clinical significance.

Few studies have examined the torque patterns produced by various isotonic machines. Harman [5] performed a torque analysis of five Nautilus machines and concluded that cam shapes would need considerable modification if they were to more closely match human strength curves as purported by the manufacturer. Lurvey et al[7] examined forces required to lift a weight through a range of motion on the N-K table, Nautilus and Universal knee extension machines. The N-K table was the only machine found to approximate the normal human strength curve for the knee extensors. Medvick and Staubers [8] examined the N-K table to determine the optimal position of the resistance arm relative to the exercise arm to best match the knee extensor strength curve. They determined the optimal angle to be 55°. Only one study could be found that examined the optimal offset angle corresponding to the torque curve for the knee flexor musculature. Noland and Kuckhoff,[9] in their article introducing the device, stated that they found an offset angle of 160° to "create a resistance curve" most closely paralleling the joint torque curves described by Clarke et a1,[1,2] but did not state how this was determined. Clarke et al[1,2] created isometric strength curves from tests of several subjects at various points throughout the range of motion. To our knowledge, the optimal offset angle corresponding to the strength curve for the knee flexor musculature has not been examined dynamically. The purpose of this study was to examine dynamically various offset angles to determine which offset produces a torque pattern most closely corresponding to the dynamic torque curve of the knee flexor musculature.

METHODS

Subjects for this study included five college-age male volunteers (age=21.8±1.8 yrs, ht=181.9±4.3 cm, wt=88.4±12.6 kg). Subjects were free from history of knee injury, and each subject signed an informed consent document. The study was conducted according to institutional guidelines.

The instrumentation, procedures, and data analysis for this study were similar to that of Medvick and Stauber.[8] Human torque curves for knee flexion were obtained on the Kinetic Communicator computer-controlled isokinetic dynamometer (Kin Com; Chattecx Corporation; Chattanooga, Tenn). The isokinetic mode was selected because it allows reliable quantification of human muscle performance.[10] Subjects only participated in the isokinetic trial. Torque curves for the N-K table (N-K Products Co, Inc; Soquel, Calif) were obtained from two tests with four different offset angles. The Kin Com dynamometer's passive mode was used to push the exercise arm through a range of motion of 0° to 90° of knee flexion, while recording the force and angular position with respect to time.

Reproducibility was measured by performing a test/retest comparison of the torque curves produced between the two trials for the N-K table. The difference in the torque curves produced between trials was calculated by the Kin Com to be 3% for the 90° offset angle, and 0% for the 110°, 135°, and 160° offset angles.

To obtain the isokinetic torque curves for knee flexion, each subject was seated on the Kin Com with his/her knee flexed to 90°. The axis of rotation of the mechanical arm of the dynamometer was set approximately 2 cm inferior and 2 cm posterior to the anatomical axis of the knee. The Kin Com lever arm was aligned with the shin pad and secured to the subject's lower leg approximately 5 cm superior to the medial malleolus. Lever arm length was recorded for each subject. Subjects were stabilized by a strap over the anterior thigh just proximal to the patella and by a strap across the pelvis. Subjects performed the testing with their arms crossed over their chest, while viewing the monitor. Consistent verbal encouragement was provided to maximize effort. The interrupted concentric/concentric protocol was used with standard Kin Com overlay. For familiarization and warm-up, each subject performed five sub- maximal contractions for extension and flexion, followed by two maximal contractions for extension and flexion, respectively. Following a 1-minute rest, each subject performed five maximal test repetitions. A 5-second pause separated each movement of extension and flexion to allow the subject to rest between each effort. Only torque curves generated during the knee flexion contractions were used for this study.

To obtain torque curves for the N-K table, the exercise arm of the N-K table was secured to the lever arm of the Kin Corn (Fig 1). It was necessary to reverse the orientation of the exercise arm relative to the resistance arm so that the resistance arm was on the inside. It was also necessary to remove the padded seat structures from both the N-K table and the Kin Com. Several 45-lb weights were placed on the base of the N-K table to stabilize it. The mechanical axes of rotation for the two machines were aligned. The resistance arm of the N-K table was loaded with 10 lbs. Trials were conducted with the Kin Com in the passive mode at 20°/s, moving the exercise arm through a range of motion of 0° to 90°. The 20°/s speed was used because it was determined in trial testing to be the fastest speed that did not compromise the stability of the set-up, and is consistent with the findings of Medvick and Stauber.[8] The offset angles were 90°, 110°, 135°, and 160°. The Kin Corn recorded the force and angular position with respect to time and calculated the values relative to torque and angle.

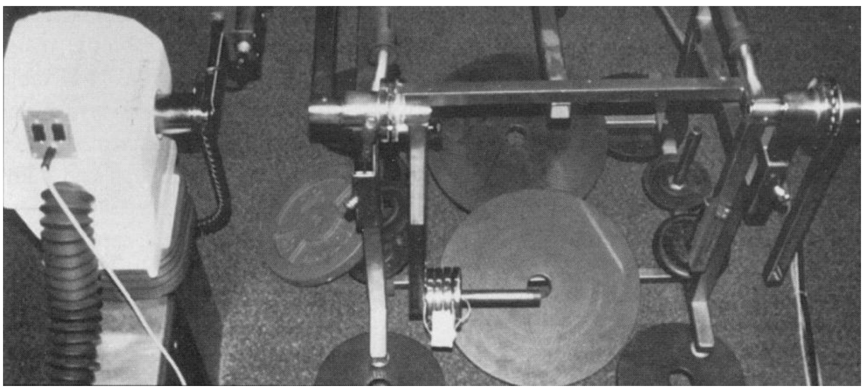
Fig 1:—The orientation of the Kin Com and the N-K table.

Mean isokinetic torque values were calculated by the Kin Com at 5° increments throughout the range of motion for each subject's three repetition overlay. These values were used to calculate mean torque values for all subjects at 5° increments throughout the range of mo tion in order to create a representative torque curve for the knee flexor musculature. These values were converted to relative mean values by dividing each value by the mean peak torque. For example, the mean torque value at 50° of 53.2 Nm was divided by the mean peak torque of 66.6 Nm, resulting in a relative mean value of .8. This procedure allowed varying amounts of absolute torque to be compared in a torque-position relationship of the same magnitude.' Torque curves for the N-K Table were obtained by recording the peak torque from one trial at each of the four offset angles at 5° increments throughout the range of motion. Four relative torque curves were generated for the N-K table in a manner similar to the isokinetic torque curves generated by the subjects. Torque values for the first and last five degrees of the 0° to 90° range of motion were excluded from comparison for two reasons. The first was to minimize the acceleration/deceleration artifact when testing the subjects isokinetically, and the second was the result of a delay in engagement between the resistance arm and exercise arm of the N-K table when testing it.

RESULTS

The representative isokinetic torque curve for the five subjects was an ascending-descending shaped curve (ROM=0° to 90°) that was primarily descending in nature. Peak torque in this curve occurred at approximately 15° of knee flexion (Fig 2).

The N-K table's offset angle of 90°, which is used often for knee flexion exercise clinically, produced an ascending curve which reached peak torque between 80° to 85° of knee flexion (Fig 2). The curve produced at the 110° offset angle was also primarily ascending in nature, reaching peak torque between 60° and 80° of knee flexion before descending slightly at 85° of knee flexion (Fig 2). When the lever arms of the N-K table offset one another by 135°, the resultant torque curve ascended to a peak torque at 30° of knee flexion, and maintained that peak torque through 55° of knee flexion before descending through the remainder of the range of motion (Fig 3). Finally, at the 160° offset angle, an ascending-descending torque curve was produced that was primarily descending in nature, reaching peak torque between 10° and 15° of knee flexion (Fig 3).

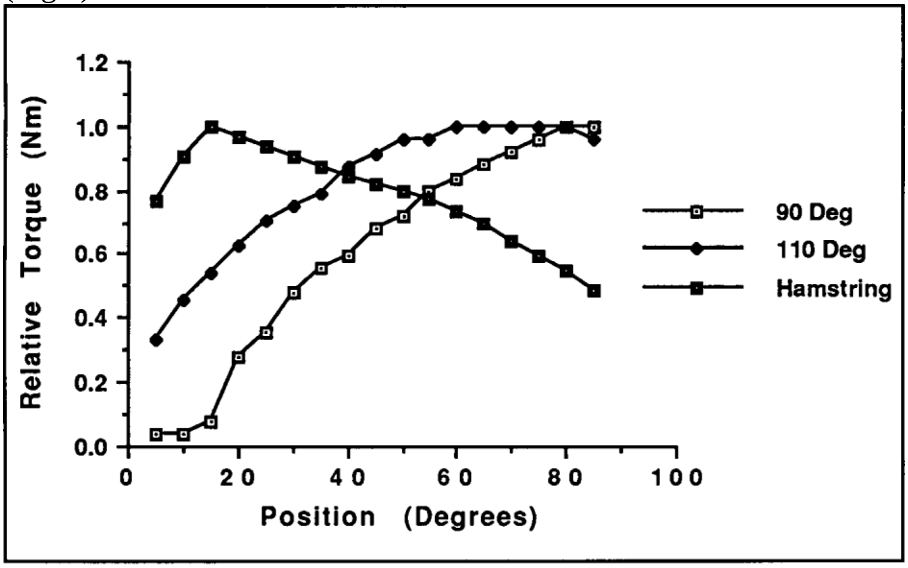

Fig 2.—The isokinetic human knee flexor torque curve contrasted with the torque curves produced with 90° and 110° offset angles on the N-K table.

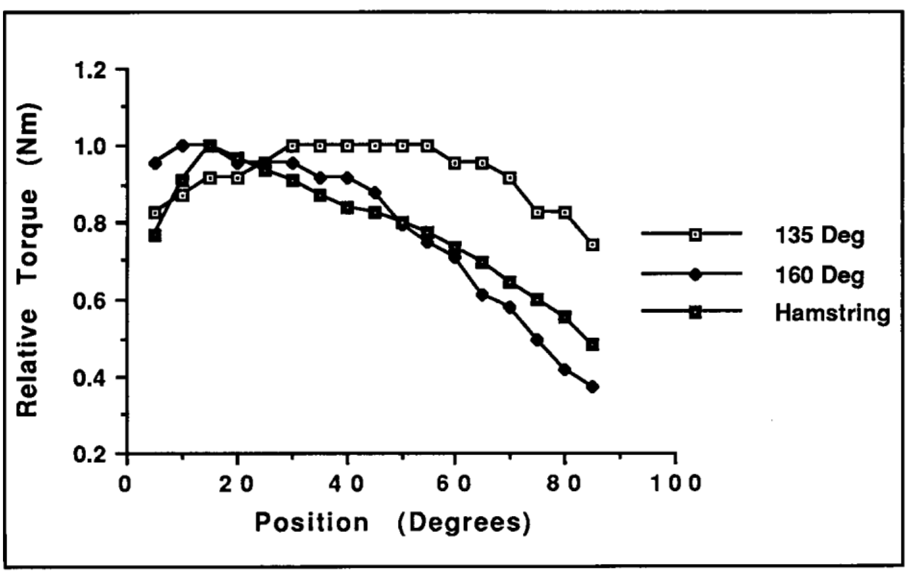

Fig 3.—The isokinetic human knee flexor torque curve contrasted with the torque curves produced with 135° and 160° offset angles on the N-K table.

2 0 40 60 80 100

DISCUSSION

Qualitative analysis suggested that the 160° offset angle most closely corresponded to the representative knee flexor isokinetic torque curve. The 90° offset angle corresponded least to the representative torque curve. These findings are consistent with those of Noland and Kuckhoff,[9] although it is not stated in their paper how they determined the optimal offset angle, and they compared offset angles to an isometrically derived torque curve in contrast to our dynamically derived representative knee flexor torque curve. Although the findings of this study seem to support dramatic alteration of common clinical practice when using the N-K table for knee flexor strength development, the 160° offset angle might be awkward to use because it has a tendency to force the user into knee hyperextension at the beginning of the exercise motion. As such, our clinical impression is that a practical compromise might be to employ either the 110° or 135° offset angle in lieu of the traditionally employed 90° offset angle. Perhaps equipment modification in the form of a range of motion stop would eliminate the problem of forced hyperextension of the knee and would allow safe and effective use of the 160° offset angle.

Little information is available regarding seated knee flexion torque curves, particularly concerning the point in the range of motion at which peak torque is normally realized. The representative torque curve found in this study was derived from a small population of college-age male subjects and, therefore, might or might not be typical of the population at large. In addition, it is well documented in the literature that torque production varies widely as a function of test velocity.[3,4,11-13] For this reason, further research is needed to establish normative data for torque curves and angles of peak torque production for seated knee flexion exercise at various test speeds. In terms of clinical importance, future research considerations also might include a training study to examine the differences between the offset angles and their effect on strength development.

The "play" in the mechanism between the resistance and exercise arms of the N-K table occurred because the N-K table used in this study was old and had some movement in the mechanism between the resistance and exercise arms. Thus, it was necessary for the Kin Com, in the passive mode, to pick up the slack in the system during the first few degrees of the motion before encountering resistance. It is interesting to note that the model of N-K table used in this study did not have consistent distances between offsets, with the first two offsets being 20° apart, and the distance between the second and third, and third and fourth offsets being 25° apart. This odd design was apparent in all three machines of the same model available to us and possibly might be attributed to wear-and-tear changes on the machines over time. Ideally, the two lever arms could offset one another at every 5° or 10°. This would allow for more flexibility in the use of the machine and more accurate testing to determine the offset which most closely approximates the knee flexor torque curve.

Torque curves for various offset angles of the N-K table for knee extension exercise have been established by the work of Medvick and Stauber.[8] Our study documents the torque curves produced for various offset angles for knee flexion exercise, and supports alteration of the use of the N-K table for common clinical practice. Further research is needed to confirm this possibility.

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