THE MEASUREMENT AND APPLICATION OF THE RELATIONSHIP BETWEEN ELBOW ANGLE AND TORQUE

Ping-Chang Lai and Tzyy-Yuang Shiang
National College of P. E. & Sports, Taiwan

The elbow joint torque is correlated with the joint angle in a certain relationship. In order to understand the relationship between the elbow angle and the torque, we designed a static elbow tensiometer to measure the elbow angle and the torque. After a series of testing, we found that the accuracy and repeatability of the joint tensiometer performed well. Fifty-one healthy subjects performed maximal voluntary elbow flexion and extension in the joint tensiometer. In elbow flexion, the maximal torque produced at the 110-degree elbow angle. In elbow extension, the maximal torque produced is at the 30-degree elbow angle. The more elbow angle increases, the less torque is produced.

KEY WORDS: joint tensiometer, elbow, angle-torque relationship

INTRODUCTION: The body movement is executed by the contraction of attached muscle pulling the adjacent bone. Through the coordination and cooperation of these joints, the body is able to perform the movements such as translation, rotation, or even complicated actions such as running, jumping and throwing. The torque produced by the joint is not constant throughout the whole process, but is highly related to the joint angle (Tichauer, 1978). Elbow is an important joint in the performance of all the common sports. Therefore this study was designed to determine the relationship of the joint angle and the torque that is produced by the elbow joint. A static elbow tensiometer is designed to measure the relationship between elbow angle and the torque produced. The reliability and repeatability of the measurement were investigated by the static elbow tensiometer. The measurement of the joint angle and the torque were also confirmed by the computer simulation.

METHODS: Study 1: the designation of the static elbow tensiometer: Static elbow tensiometer is based on a torque transducer along with a length-adjustable hand grip and an goniometer. The muscle is capable of making a maximal isometric contraction of flexion or extension through the whole range of motion (ROM) of the elbow joint by changing the joint angle which is based on 10 degrees as a unit. The relationship between the angle of flexion or extension of the elbow joint and the torque produced can be plotted using these data. After the static elbow tensiometer set up, the reliability was examined first. A model with all the practical variables is set up by the computer simulation program Working Model 2D (Ver. 4.0; Knowledge Revolution). The Pearson's correlation coefficient between the values measured with the static elbow tensiometer and the values obtained from the computer simulation model were determined under the same conditions. Furthermore, the experiments include (1) the gravity correction of the 27 cm handle (0.65 kg in weight) from 0 to 180 degrees and (2) measuring the torque value of the handle connected to a 1.3 kg object (27 cm in length) from 0 to 180 degrees. Both experiments continued for one week, then the day to day correlation as well as the correlation between the measured values and the values obtained from the computer simulation model were calculated. The repeatability of the static elbow tensiometer was examined by ten healthy college subjects. The subjects were asked to complete the first measurement of torque produced by the flexion of the right and left elbow joint with the static elbow tensiometer, then the measurement was repeated after an interval of 2-15 days, comparing the Pearson's correlation coefficient between the values obtained from both of the measurements. The torque value produced by each person at the angle of 110 degrees (the angle that produces the largest torque) was also measured. The difference was investigated by the Paired t-test.

Study 2: the relationship between elbow angle and torque: Nineteen normal healthy males, 17 baseball players and 15 normal healthy females were asked to perform elbow flexion and extension from 30 to 170 degrees, and the torques produced were measured. The graph of the relationship between joint angle and the torque can be obtained. The basic information of the subjects is listed as followed.

Table 1 Basic Information of the Subjects (Mean ± SD)

	Normal males (N=19)	Baseball players (N=17)	Normal females (N=15)	Average (N=51)
Age	26.63 ± 3.4	19.89 ± 0.6	27.87 ± 4.6	24.75 ± 4.8
Weight(kg)	72.21 ± 10.0	74.47 ± 7.0	56.80 ± 6.9	68.43 ± 11.1
Height(cm)	176.58 ± 6.9	175.41 ± 4.9	162.47 ± 6.3	172.04 ± 8.7
length of forearm(cm)	32.80 ± 1.5	32.94 ± 1.0	30.69 ± 2.2	32.05 ± 2.0

RESULTS AND DISCUSSION: Study 1: The designation of the static elbow tensiometer: The components of the static elbow tensiometer are shown in Figure 1.

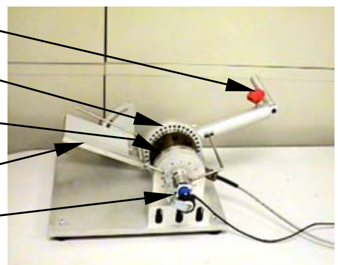

Figure 1 - The components of the static elbow tensiometer.

Gravity correction: the model was set up according to the static elbow tensiometer by the computer simulation, then compare the torque values gained from 0 to 180 degrees by the simulation with the experimental values. The Pearson's correlation coefficient is 0.997.

The object of 1.3kg load is hung on the handle to compare the result of the computer simulation and the experiment with the change of angle from 20 to 170 degrees. The Pearson's correlation coefficient is 0.999 which means they are significant correlated as shown in Figure 2. In addition, the measurement was continued for 7 days, then Paired T-test is applied to compare the differences of each measurement at 110 degrees. No difference was observed in the result.

Concerning the study that was done with the static elbow tensiometer, we believe that it is a reliable device. The torque that is measured by the torque transducer is based mainly on the handle grip, therefore it is necessary to make the gravity correction before each measurement is done (Fillyaw et. al. 1986). We found that the handle grip of the static elbow tensiometer does not affect considerably to the true experimental value, only 0.2N-m at most. In the condition of bearing weight, the values obtained from each angle and from the computer simulation (ideal status) showed obvious correlation (r=0.999). In a continuous measurement of 7 days, the correlation between day to day are all above 0.992 (data not shown). Besides, no differences was found when Paired T-test was applied to compare the torque when the angle of the handle grip was set to 110 degrees.

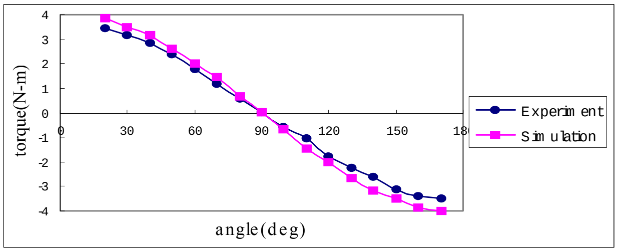

Figure 2. Compared the experimental values with the value obtained from computer simulation. (r=0.999).

Ten subjects were asked to perform elbow flexion with their left and right hands for two times within an interval of 2-15 days to determine the repeatability of the static elbow tensiometer. The relative values are shown in Table 2. The Paired T-test was applied to compare the values gained when the angle was set to 110 degrees. No difference was observed. The subjects have their right elbow joint angle and the torque produced measured during an interval of 15 days, all the correlation coefficients obtained were higher than 0.727.

Table 2 The Repeatability of the Static Elbow Tensiometer

	Sub1	Sub2	Sub3	Sub4	Sub5	Sub6	Sub7	Sub8	Sub9	Sub10
r of right hand	.761**	.954**	.924**	.85**	.881**	.811**	.984**	.864**	.904**	.92**
r of left hand	.727**	.946**	.941**	.918**	.925**	.874**	.942**	.869**	.946**	.864**
Interval days	2	2	3	5	6	7	7	8	8	15

** P<.01 significant correlation, r value: Pearson's correlation coefficient

Study 2: the relationship between elbow angle and torque: The relationship between elbow angle and torque are shown in Figure 3 and Figure 4. Running the Working Model simulation program with all the input physical variables, and then export the results to a text file, which is then converted into a Microsoft Excel file. The data is used to perform statistical analysis. Figure 5 shows the computer simulation process and the results.

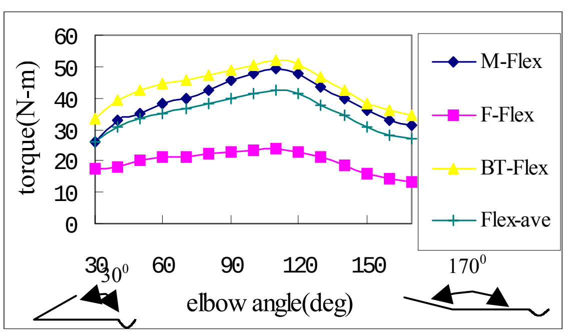

Figure 3 - The relationship of elbow joint flexion angle and torque produced.

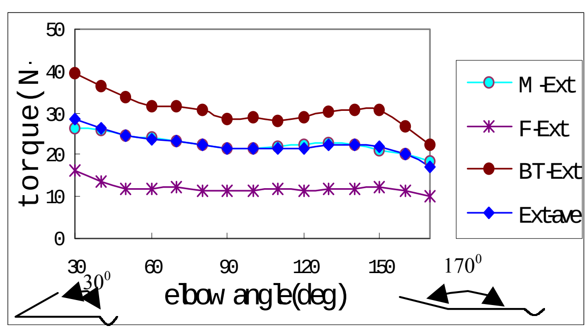

Figure 4 - The relationship of elbow joint extension angle and torque Produced.

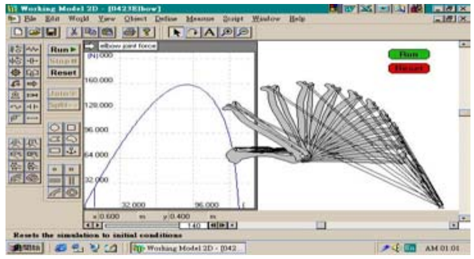

Figure 5 - The correlation graph between computer simulation of elbow joint flexion angle and the torque produced.

According to the result gained from Study 2, we found that when the elbow joint is flexed to 110 degrees, the maximal torque could be obtained. Change of elbow angle from 180 degrees to 110 degrees resulted in gradual increase in torque value, and when the angle started to drop from 110 degrees, the torque produced also decreased correspondingly until the joint was completely flexion. In the part of elbow extension, we found that when the joint was extended to the minimal angle (full extension, approximately 30 degrees), the torque produced was relatively higher. With the increase of angle, the torque produced began to decrease. But the difference between the maximal and minimal torque values was not as obvious as shown in the "flexion" part. Through simple computer simulation analysis, we found that the maximal contraction force can only be produced with a proper angle (approximately 110 degrees), but not with too large or too small angles. This trend was correspondent to the experimental results.

CONCLUSION: The static elbow tensiometer showed its performance to a certain extent in stability and in the application to human experiments, but further analysis is necessary when compared to other dynamometer. Furthermore, when observing the relationships between the joint angle and the torque that are obtained from isometric concentric contraction measured in human elbow joints, we can find that the relation between the joint angle and strength is changed in accordance with the different types of action, and this information is extremely useful to design the training program or even design the muscle training equipment.

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