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# Influence of the dynamometer driving mechanism on the isokinetic torque angle curve of knee extensors

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**Summary**

The purpose of this study was to assess the effect of the type of isokinetic driving mechanism on the torque angle curves of the knee extensors. Twenty healthy volunteers (11 male and 9 female) were tested alternately on an active and on a passive dynamometer. The active dynamometer (Quadriceps Dynamometer), provided with a starting threshold and a controlled acceleration, produced a curve with high torque readings in the first part of the range of motion. Subsequently a rather flat curve is found with a mean maximum torque of 158 N m at a joint position of 119° (angular velocity 90° $s^{-1}$). The passive dynamometer (Cybex II) produced a curve with low torque readings in the initial phase and a mean maximum torque of 179 N m at a joint position of 123°. The maximum torque differences were statistically significant ($P<0.05$). It is concluded that the driving mechanism of the isokinetic device has a considerable influence on the initial phase of the torque angle curve and on the height of the maximum torque produced by the knee extensors.

**Relevance**

Isokinetic torque measurements of the knee extensors are performed by many clinicians and researchers. The results of this study suggest that the driving mechanism of the measuring device may exert an important influence on the shape of the torque angle curve. In interpreting the results of such tests, one should bear in mind the possibility of certain parts of the torque curve being artefacts instead of a reflection of the performance of the knee muscles.

Key words: Isokinetic, knee extensors, dynamometry

## Introduction

Isokinetic dynamometers are frequently used to measure the torque exerted by the knee muscles or other muscle groups such as those acting on the hips, the shoulders, or the back. Basically the design of these devices is simple: a rotating lever arm counteracts the moment exerted by the contracting muscles and the limb is allowed to move through a certain angular range of motion at a constant angular velocity. The isokinetic motion of the limb segment is provided by either a hydraulic system or an electric motor.

The hydraulic system is used in passive dynamometers such as the Cybex II. The moment imposed on the lever is transmitted to a hydraulic mechanism where the fluid rate of flow through an outlet nozzle is controllable through a closed feedback loop. This fluid rate determines the constant angular velocity of the lever arm. This machine is used in most studies on isokinetic strength testing, and the torque angle curves generated by this passive system were generally accepted as representative for the isokinetic curve of a muscle group.

The torque angle curve of the Cybex II is characterized by an initial phase of uncontrolled

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acceleration. In this phase, when the subject increases the speed of the lower leg and the lever arm from zero to a preselected angular velocity, no torque is registered[2,3]. After accelerating to this preset velocity, the torque rapidly builds up. In this early phase of the isokinetic movement, after transition from the unresisted (uncontrolled acceleration) to the resisted (isokinetic phase) contraction, large fluctuations may be seen in the torque values recorded. The accelerating lower leg is abruptly inhibited from further acceleration and there is an impact between the accelerating mass and the resisting lever arm. The impact is followed by a period of fluctuating torque values which might interfere with an accurate interpretation of the torque angle curve[4]. To overcome this, the Cybex II is equipped with a system to dampen the effects of the impact of the accelerating limb. The fluctuations are evened out by the damping system and a smooth curve, with a readily identifiable maximum torque value, is generated[5].

In active isokinetic systems an electric motor dictates the constant velocity of the lever arm.

Active and passive systems, however, may produce torque angle curves with different shapes, and the system may thus influence important parameters such as the maximum torque value or the position in the angular range of motion (ROM) where maximum torque occurs (maximum torque joint position). The purpose of this study was to compare a passive and an active isokinetic dynamometer with respect to the torque angle curve of the knee extensors.

## Materials and methods

Twenty healthy volunteers (11 male and 9 female), with a mean age of 30 years (range 25–38) participated in this study. None of the subjects had a history of knee injury or experience with isometric or isokinetic dynamometry. Each subject was tested on a passive and an active system in one test session and the sequence of the first and the second dynamometer was changed for every new subject.

The passive system of the Cybex II was used because this dynamometer is the one most frequently used in research and clinical practice.

The Quadriceps Dynamometer (QD, Figure 1) was used as the active system. This device is operated by a high instantaneous torque AC motor (power = 0.6 kW). The available torque of the motor (2.6 N m at 2400 rpm) is sufficient to measure torques at a maximum angular velocity of $90° s^{-1}$. The angular velocity range is therefore limited and corresponds to $0–90° s^{-1}$. The range of motion of the lever arm, and thus the knee joint, is limited by means of electrical switches and mechanical stops and can be preselected anywhere between 60° of flexion and 180° of extension (maximum extension, 180°). Angle, speed and torque are simultaneously recorded on a W + W four-channel pen-recorder (Electronic AG, Switzerland, model 314).

Calibration of the torque transducer is performed

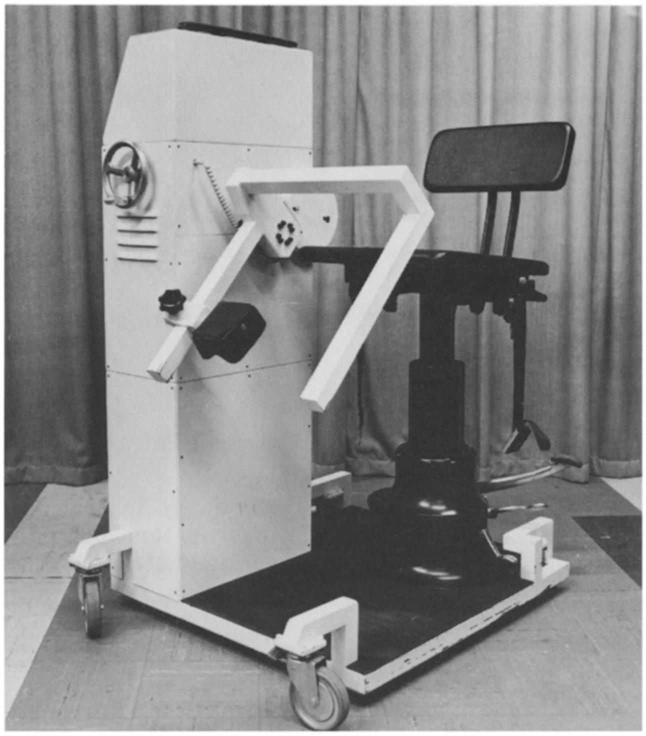

**Figure 1.** The Quadriceps dynamometer.

under isometric conditions with known weights. Correction for gravity was not carried out.

The QD was designed and built by the Central Research Laboratories of the Erasmus University Rotterdam and a more detailed description of the QD is provided by Pronk and Niesing[6].

The subjects were positioned on the respective dynamometers according to the principles described by Goslin and Charteris[7]:

*Parallel alignment*

The moving limb segment is aligned parallel to the lever arm of the arm of the dynamometer.

*Rotational alignment*

The axis of rotation of the joint and the axis of rotation of the lever arm coincide.

*Stabilization*

Limb segments that are not supposed to contribute to the force exerted on the lever arm are not allowed to participate. In the case of dynamometry of the knee extensors, the tendency for the pelvis to lift during an all-out effort is prevented by having subjects hold on to side handles on the seat base[8] and by strapping the upper legs with a belt of 5 cm width.

Before actual testing the subjects were informed of the aim of the measurements and instructed how to perform a concentric maximal voluntary contraction. Subsequently the subjects were allowed to exert three submaximal contractions to become familiar with the testing procedure. Only the dominant leg was tested with both devices, and dominance was determined by asking the subject which leg he preferred for kicking a ball. The maximal tests were performed at an angular velocity of 90° $s^{-1}$. To prevent fatigue and to reduce the duration of the protocol, no other speeds were used. During the maximal tests the subjects were instructed to extend the knee as fast and powerfully as possible. The best of three contractions was registered, with 1-min intervals being allowed between the maximal tests.

## Results

The means and standard deviations of maximum torque values, maximal torque joint position and work are presented in Table 1.

Mean maximum torque values produced on the Cybex II were higher than on the QD for both the male and female subjects. This difference amounted to about 10% and was statistically significant ($P<0.05$; Student paired *t*-test). The values of maximal torque joint position on the Cybex are higher than on the QD for the male subjects, but not for the female subjects. There were no relevant differences in the mean work produced on the respective dynamometers.

To simplify the further discussion on the shape of the curves the data of the male and female subjects were combined and mean torque angle curves of the group were composed from the individual curves. The results are shown in Figure 2.

The Cybex II torque recording shows a phase were no torque is registered during the initial part of the ROM. Subsequently torque builds up rapidly.

The torque angle curves of the QD and the Cybex II coincide at 103°. During the second part of the angular range of motion (ROM), mean torque registered on the Cybex II is higher than on the QD.

## Discussion and conclusions

The results of this study show that the shape of the torque angle curves (and some parameters derived from them) obtained with a passive and an active dynamometer may differ significantly.

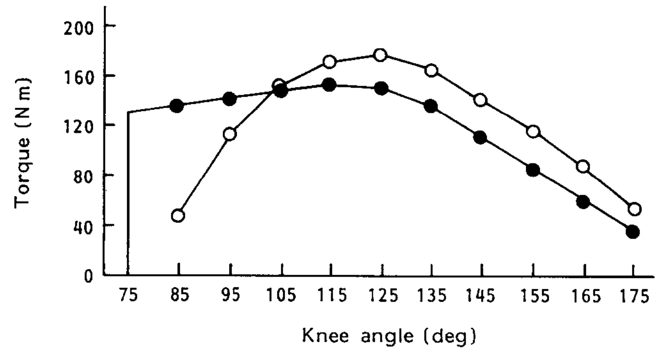


**Figure 2.** Mean torque angle curves of the knee extensors on: ○, the QD; and ●, the Cybex II at an angular velocity of 90° $s^{-1}$.

In comparison with the active system, the value of the mean maximum torque of the knee extensors produced on the passive system is significantly higher in both the male and female subjects. A practical consequence of this finding is that in the interpretation and comparison of strength testing data the type of system used (active or passive) should be taken into account.

The driving mechanism also seems to have some influence on the maximal torque joint position (the position in the range of motion where maximum torque is found), but the differences are statistically significant only in the male subjects. No clear explanation for this discrepancy can be given.

The mean work values are not significantly different. Work is primarily determined by the shape of the curve, as discussed below.

The torque angle curves of the Cybex II and the QD show striking differences especially during the initial phase of the contraction. These differences can be partially explained by the way the contraction is started. In the active system (QD) a torque threshold (usually 10 N m) synchronizes the start of the contraction of the knee extensors and the start of the lever arm movement of the dynamometer. This results in an isometric phase which allows the knee extensors to build up a considerable part of their force before the actual dynamic phase begins. After the isometric phase the lever arm is accelerated by the driving mechanism

**Table 1.** Means (SD) and statistical significance of maximum torque, maximum torque joint position, and work of men and women at an angular velocity of 90° $s^{-1}$ on the Cybex II and the QD

| | *Cybex II (passive system)* | | *QD (active system)* |
|---|---|---|---|
| Men 90° $s^{-1}$ | | | |
| Mean max. torque (N m) | 207 (33) | * | 180 (31) |
| Mean MTJP (deg) | 123 (7) | * | 114 (13) |
| Mean work (Joule) | 254 (47) | | 246 (40) |
| Women 90° $s^{-1}$ | | | |
| Mean max. torque (N m) | 139 (25) | * | 120 (17) |
| Mean MTJP (deg) | 124 (4) | | 120 (17) |
| Mean work (Joule) | 168 (26) | | 168 (27) |

MTJP, maximal torque joint position.
*Statistically significant difference, $P<0.05$.

with a controlled acceleration of 300° $s^{-2}$. The low initial torque of the passive system (Cybex II) is caused by the absence of a torque threshold and by the initial uncontrolled acceleration during which no torque is registered. The passive system seems to 'underestimate' the performance of the knee extensors between 75° and 95°. The curve of the QD, however, shows that the knee extensors are capable of producing a considerable amount of torque between 75° and 95° under dynamic conditions. Williams and Stutzman[9], describing the isometric strength variation through the range of joint motion, found a knee extensor torque angle curve that is very well comparable with the isokinetic curve produced by the QD, even at joint positions of 75° and 95°.

The second half of the curve of the QD is lower than the Cybex curve. This could be explained by the fact that with the QD a considerable amount of energy is used in the isometric and early isokinetic phase. The low initial torque of the Cybex II leaves more energy for the second half of the contraction, which results in a higher torque.

It is not clear to what extent overshoot (i.e. an erroneously high reading in electromechanical systems) contributes to the higher maximum torque and the higher second half of the curve of the Cybex II. This overshoot is an artefact and consists of a torque tracing that occurs when the subject reaches the preset velocity after the unresisted acceleration[4]. Unlike the Cybex dynamometer the QD is provided with a controlled acceleration and this kind of overshoot does not occur.

The conclusion of this study is that the first part of the torque angle curves of the QD and the Cybex II differ considerably. The second part of the curves has approximately the same shape. The driving mechanism of the Cybex II and the QD is, to a large extent, responsible for the difference in shape of the two torque angle curves. The value of the maximum torque of the knee extensors measured with the active system is about 10% lower than the values resulting from the test performed with the passive system.

In comparing the results of strength tests, one should interpret the data bearing in mind the design of the dynamometer used.

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