Effect of Starting Angle on Isokinetic Torques

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INTRODUCTION

In the past few years, the isokinetic dynamometer Cybex II has been widely used to determine the force-velocity relationship of knee extensor muscles (KEM) and of other muscle groups (3).

In 1978 Perrine and Edgerton (4), studying the knee extensor muscles, stated that: «An angle sufficiently distal to the starting point in the range of movement, 30° before full extension, was selected as the specific angle for torque measurement. This enabled all the torque measurements to be made both after the subject muscle had completed its initial build up to full tension, and after the inherent initial energy oscillations through the total (muscle-instrument) system had subsided, even at the highest test velocity (and thus the sortest time-duration)».

However there are still some disadvantages even if readings are taken near full extension. First of all, at 30° before full extension the mechanical output of KEM, as inferred from maximal isometric torque (MIT), is about 50% of that developed at 80° before full extension (angle where MIT occurs) (2). Furthermore, the time spent to reach 30° before full extension at 300°/s (highest angular speed of the isokinetic dynamometer Cybex II) is 220-240 msec; after which time, untrained subjects develop about 70% of maximum isometric tension (1). Although this is a conservative estimate of the role played by contraction duration since, under isokinetic conditions, the process of tension development would inevitably be longer than under isometric conditions for the amount of shortening of contractile elements in this case is far less. However other factors work in the opposite direction; in fact at 300°/s peak torques occur after about 150 ms from the initial development of tension because after this time both muscle length and lever system become too disadvantageous.

At low angular velocities muscle fatigue could possibly decrease maximal torque and the closer to full extension, the greater will this effect be (4).

At all angular velocities an increase of starting angle would have three different effects. Firstly, of allowing peak torques to be developed at an angle even further from full knee extension; secondly, of giving more time to complete muscle tension development at a given angle; thirdly, of increasing the possibility of fatigue occurring as a greater amount of work is done at low speeds.

Aim of this study was to verify the effect of increase of range of movement on torques developed by leg extensor and hip flexors muscles.

MATERIAL AND METHODS

Eight sedentary male subjects (age 23.8 ± 3.5 years, height 178 ± 6.0 cm, weight 74.8 ± 9.8 Kg) took part in the experimental sessions. Subjects were instructed to carry out maximum isokinetic contractions of the knee extensor muscles (KEM) and the hip flexor muscles (HFM), on separate occasions. The KEM were tested at five angular speeds 60, -120, 180, 240 and 300°/s while the HFM were only tested at 180°/s.

One set of contractions was carried out at each angular speed. Each set consisted of four repetitions carried out with two conditions, alternatively. In the first condition the contraction started from the standard angle (SA) of isokinetic testing of KEM and HFM (90° before full extension for KEM and 180° before full flexion for HFM). In the second condition the contraction started from an increased angle (IA) which was 30° for both muscle groups (i.e. starting from 120° before full extension for KEM and 30° before the vertical for the HFM). A time interval of 30 seconds was allowed between each repetition and 3 minutes between sets at different speeds. Torques of KEM were read at maximum peak (MPT) and at 60°, 45° and 30° from full knee extension; those of HFM were read at maximum peak and at 15° of hip flexion from vertical. All torque data were corrected for gravity effect and damping factor 2 was used in all trials, according to the manufacturer's recommendations (Cybex II Lumex Inc. N.Y.). In both IA and SA conditions electromyographic activity (EMG) of KEM was recorded by placing two surface electrodes on the Vastus lateralis. The EMG signal was amplified with a Bioelectric carrier amplifier (8811A Helwett Packard) and passed through an upper (1000 Hz) and lower (5 Hz) cut-off filters. The amplified signal was then full wave rectified and passed through a first order filter with a time constant of 25 msec, corresponding to a cut-off frequency of 6 Hz. The resulting linear envelope (iEMG) was displayed together with torque and joint angle on a chart recorder (Fig. 1). For each subject, a mean value of torque and EMG was calculated from values of each set and a grand mean of all subjects was obtained. Statistical differences in torques and iEMG between the two conditions were assessed by means of a paired Student's -t- test.

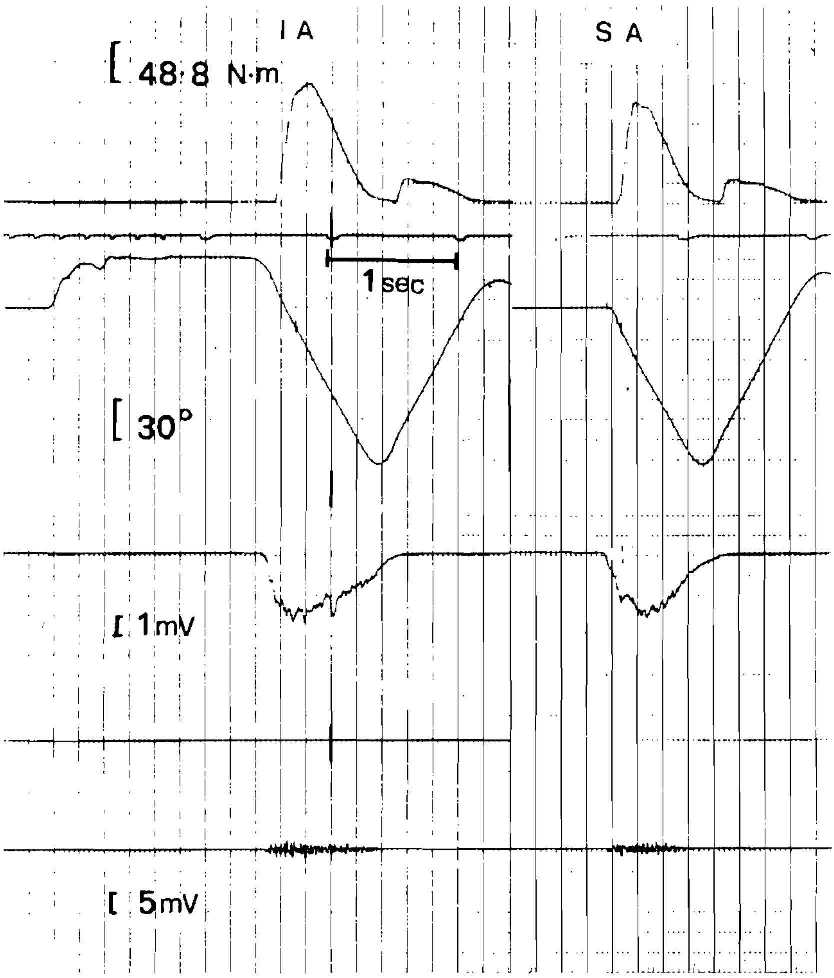

Fig. 1. (from top to lower trace): Knee extensors torque, angular position, iEMG and raw EMG at 180°/s for increased (IA) and standard angle (SA) conditions at 180°/s.

RESULTS AND DISCUSSION

MPT peak torque joint positions of KEM during contractions with the two different starting angles are shown as a function of angular speed in figure 2 and 3. Maximal torques at 45° before full extension as a function of angular speed are plotted in figure 4. In both figure 1 and 3 torques decrease with speed but the classical hyperbolic functions are less evident than those found by other Authors (3,6).

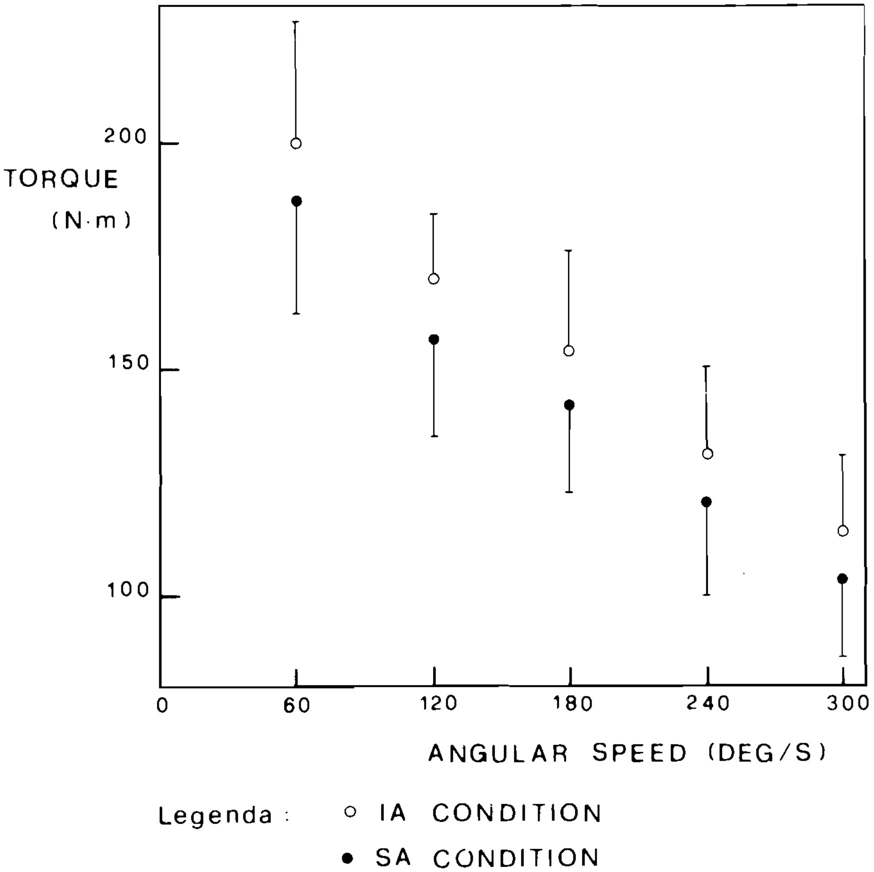

Fig. 2. Knee extensor muscles. Peak torque (means ± 1 s.d., n = 8).

Both for SA and IA conditions at 300 °/s maximal torques at 45° before full extension were 38% and 34% lower than those at 60°/s both for SA and IA conditions. These changes may be easily explained on the basis of the well known force-velocity relationship. The corresponding changes in peak torque were larger, i.e. 45% and 43%; this is due to the fact that as angular velocity increases peak torques are developed nearer and nearer to full knee extension, thus at angles which are further and further from the optimum angle.

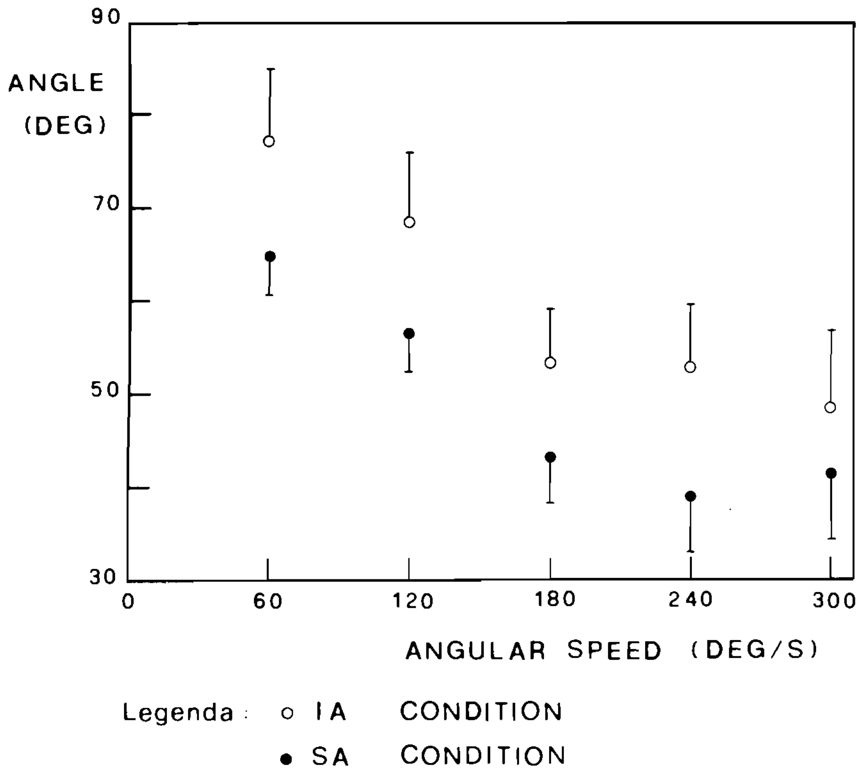

Fig. 3. Knee extensor muscles. Peak Torque joint position (means ± 1 s.d., n = 8).

We have already pointed out that near to full extension the external mechanical output of KEM decreases. However this length related effect seems rather small when compared to torque changes at different knee angles in isometric conditions (2).

The differences in maximal torques at 45° measured in SA and IA at 45° were significant ($p < 0.01$) at all but the lowest angular speed while at 30° the difference was only significant at the highest angular speed (fig. 5). The higher values of torque observed in IA conditions were indeed expected since muscles had more time to develop tension. The weight of this time factor must be more evident at high contraction speeds. The

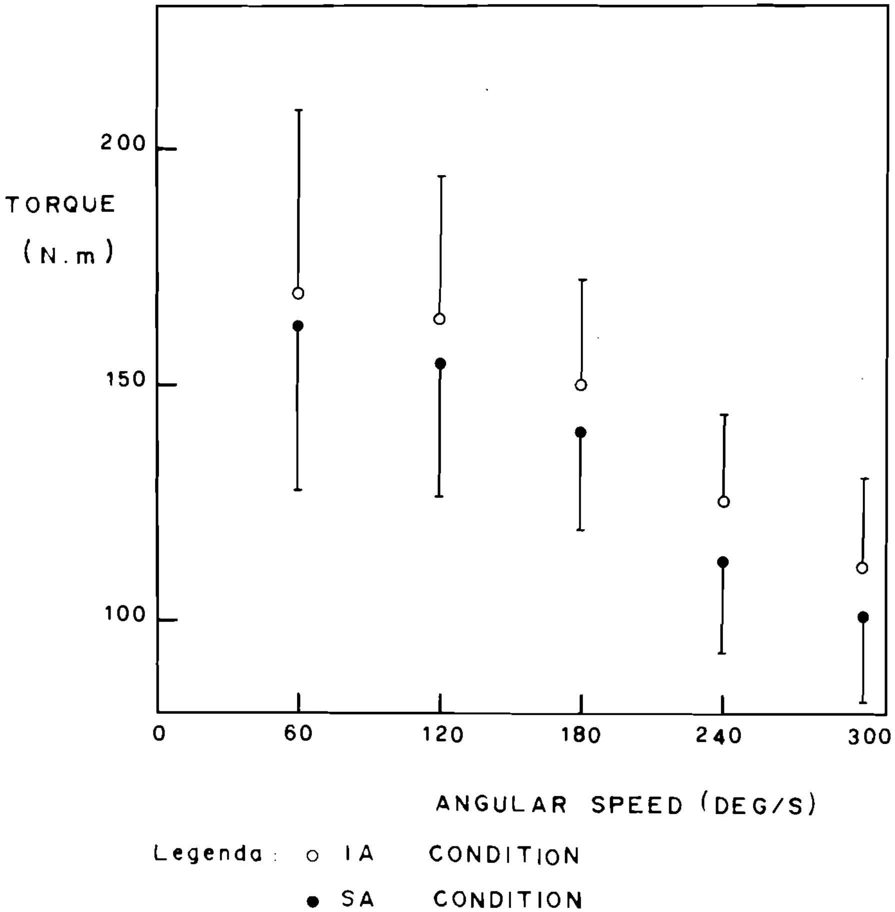

Fig. 4. Knee extensor muscles. Maximal torque at 45° from full extension (means ± 1 s.d., n = 8).

EMG measurements did not show any statistical difference at these angles; therefore there was no evidence of a different pattern of activation.

The differences in MPT were significant at all angular speeds and somewhat larger than those in maximal torques at a given angle; this is a reasonable result since in IA conditions MPT occured even further before full extension. In other words a length and a time factor are simultaneously operating.

As far as HFM are concerned similar results were obtained. MPT in IA conditions occured 31° before that in SA conditions and was higher by 10.3 ± 6.8 N*m ($p < 0.01$). Differences in maximal torques were 51.3 ± 10.6 N*m ($p < 0.01$) at 15° from vertical and 11.8 ± 9.0 N*m (NS) at 30°.

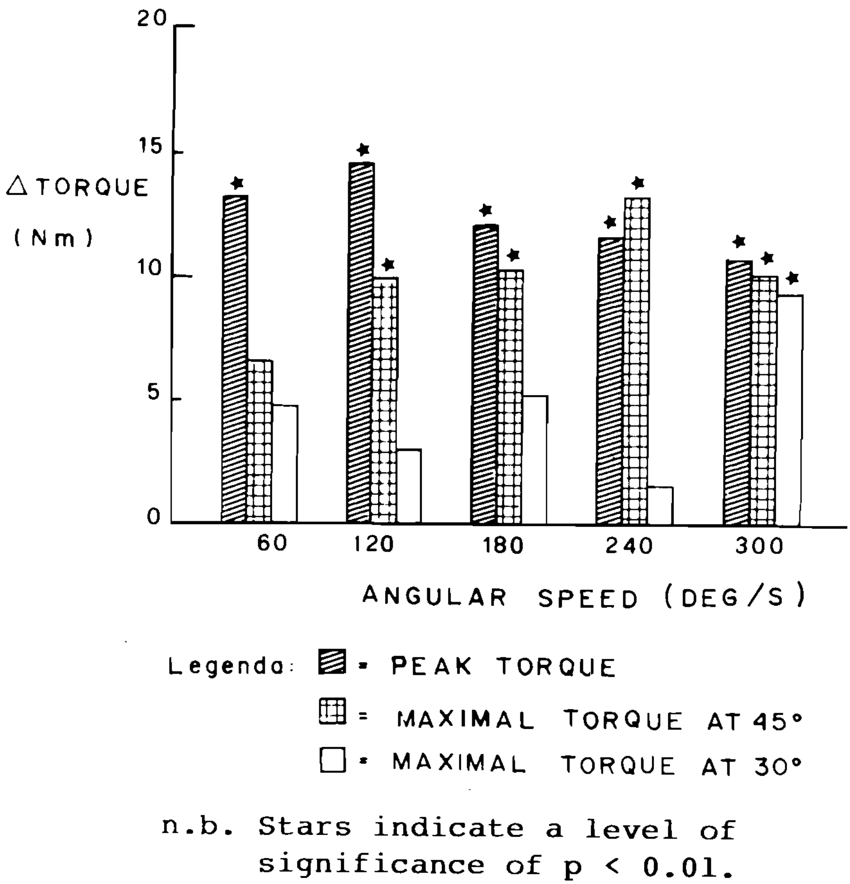

Fig. 5. Differences in peak torque, maximal torques at 45° and 30° before full extension between IA and SA.

As pointed out by A.A. Sapega at al. (5), the use of damping factor II of the Cybex apparatus does not reduce the overshoot phenomenon selectively and hence has limited value when testing muscle groups at high angular speeds; for this reason results obtained at these speeds must be regarded with caution. However it seems rather unlikely that the observed difference between torques in SA and IA conditions could be affected by the damping factor.

In conclusion in isokinetic conditions an increase of starting angle rises the external mechanical output of knee extensor and hip flexor muscle. This effect is rather small but highly significant particularly at high angular speeds.

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