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QUADRICEPS ACTIVATION AT DIFFERENT HIP AND KNEE JOINT ANGLES

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INTRODUCTION

The method of Herzog and ter Keurs [1] permits the reconstruction of the force-length curve of bi-articular muscles for individual subjects. This method assumes that for a bi-articular muscle crossing two joints, A and B, the variation in the output at Joint A in response to a change in the angle of Joint B can only be due to the force-length properties of the bi-articular muscle since the contribution of mono-articular muscles crossing Joint A would be constant. This method is useful in understanding the extent of variability in the expressed section of the force-length relationship as it allows the determination of the force-length relationship for individual subjects rather relying on the averaging of data across subjects. Such inter-individual variation is important since it may have an influence on the quality of movement and muscle co-ordination.

An important assumption of the method of Herzog and ter Keurs [1] is that the activation of the mono-articular and bi-articular muscles is constant across different joint configurations. Previous work using a muscle model to validate the method of Herzog and ter Keurs [1] has shown that the method is robust to random and systematic errors arising from incomplete activation of up to 20% of the maximum joint moment for a given position [2]. Nevertheless, if it could be shown that the degree of quadriceps activation across different hip and knee joint configurations were reasonably consistent, this would provide additional support for the reliability of the method. The purpose of this study was to measure the degree of quadriceps activation across different hip and knee joint angle configurations using doublet interpolation [3].

METHODS

Five subjects (mean \pm standard deviation age: 30.8 \pm 3.8 years; mass: 72.7 \pm 13.9 kg; height: 1.77 \pm 0.10 m) were familiarized with the procedures and provided written informed consent. The University

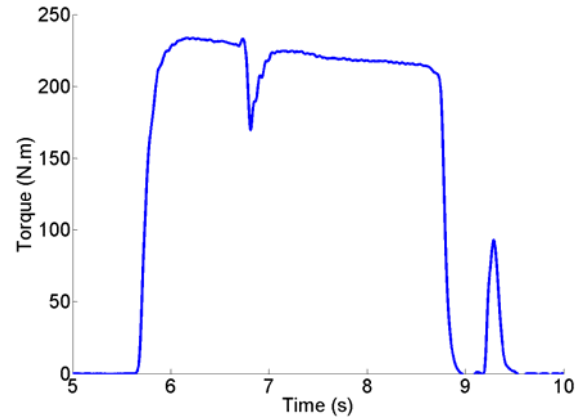


Figure 1: Example of a torque profile recorded during a maximum voluntary contraction with a superimposed doublet and subsequent potentiated doublet torque.

Ethics Committee for Research Procedures at Aberystwyth University approved all procedures. Subjects performed a five minute cycle ergometer warm-up and then performed maximal isometric knee extension contractions using the right leg in a Biodex III dynamometer (Biodex Medical Systems, Shirley, NY) in the following hip and knee angle configurations (full hip and knee joint extension being defined as 0 degrees): a 0 hip angle and a 10, 90 and 110 degree knee angle, a 55 degree hip angle and a 10 and 90 degree knee angle, and an 85 degree hip angle and a 10, 90 and 110 degree knee angle. These positions were chosen to reflect a range of vasti and rectus femoris muscle lengths. Subjects were asked to perform two maximal efforts in each position. The order of presentation of the joint configurations was randomized for each subject. Care was taken to correctly align the dynamometer axis with the lateral femoral condyle in each position before each trial. The lower leg was firmly attached to the lever arm above the ankle using a padded Velcro strap, and straps secured firmly across the waist and both shoulders. Before each contraction a baseline recording was taken to account for any passive torque, this was subtracted from the Biodex record. The Biodex output was

sampled at 1,000Hz and was low pass filtered using a zero lag fourth order Butterworth filter with a cut off of 40Hz.

Carbon rubber electrodes (12 x 10 cm, EMS Physio, Oxfordshire, UK) coated in conductive gel were placed on the anterior thigh and secured using elastic Velcro bandages. The cathode was placed on the midline of the thigh at 30% of thigh length measured in the seated position from the anterior superior iliac spine to the superior border of the patella, the anode was positioned 8 cm proximal to the superior border of the patella over the vastus medialis. A constant-current, variable-voltage stimulator (Digitimer DS7AH, Welwyn Garden City, UK) was used to deliver doublet stimuli (100- μ s pulses, 10-ms interval) at 400 V. During a familiarization visit, the current was increased in steps of 10 mA from 100 mA until no further increase in potentiated doublet torque occurred. The current was then increased by a further 10 mA (range utilized, 310–430 mA). These stimuli were tolerated without discomfort. The superimposed doublet and the potentiated doublet measured after the contraction of interest (Figure 1) were used to compute voluntary activation as a percentage of maximal activation. The potentiated doublet torque was calculated as the peak torque achieved following the doublet stimuli delivered 1 s after the contraction, and the superimposed doublet torque was calculated as the increase in torque immediately following the stimuli delivered 1.5 s after the start of the contraction.

The highest activation achieved in each joint configuration was used in the statistical analysis. The Freeman and Tukey [4] transformation was applied to the percentage activation results in order to transform the percentages to a normal

distribution. A one-way repeated measures ANOVA with alpha set at 0.05 was performed on the transformed results to determine whether significant differences in the degree of voluntary activation existed between joint configurations.

RESULTS AND DISCUSSION

Data from six contractions was rejected since the doublet had not successfully been delivered during the maximum part of the contraction. The mean activation in each joint angle configuration was above 90% (Table 1) and there was no significant effect of joint position on the degree of activation ($p=0.096$, power=0.806). The variation in activation across joint configurations for all subjects was within the level of noise simulated in the model-based validation of the method [2].

CONCLUSIONS

These results provide evidence that the degree of quadriceps activation is consistent across different hip and knee joint angle configurations. This suggests that the assumption of consistent activation at different knee and hip joint positions is reasonable and provides further evidence that the method of Herzog and ter Keurs [1] is reliable in determining the section of the force-length relationship that different subjects operate over.

REFERENCES

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4. Freeman MF and Tukey JW. *Ann Math Statist*, **21**, 607-611.

Table 1: Mean and standard error (SE) percentage activation in the different joint configurations (0 degrees represents full hip or knee extension).

Hip Angle (degrees)	0	0	0	55	55	85	85	85
Knee Angle (degrees)	10	90	110	10	90	10	45	90
Mean % Activation	96.2	91.3	94.1	96.8	91.6	98.3	92.7	95.0
SE % Activation	1.7	2.8	1.7	1.6	2.7	1.3	1.9	2.5