THE EFFECT OF MULTIPLE MEASUREMENT ANGLES ON THE PREDICTION OF JOINT TORQUE-ANGLE PARAMETERS

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INTRODUCTION

The joint torque-angle relationship exhibits a bell-shaped curve, where peak isometric torque occurs in the mid-range. This relationship has previously been modelled using a quadratic function where parameters are optimised to best fit experimental data [1]. Experimental joint torque is typically measured at multiple joint angles throughout the joint range of motion using an isokinetic dynamometer [1,2]. Despite this, it is currently unknown how the number and location of these measurement angles affects prediction of the torque-angle relationship. The purpose of this study was, therefore, to investigate the effect of multiple measurement angles on the prediction of the torque-angle relationship for knee flexors and knee extensors.

METHODS

A two-parameter quadratic was used to model torque production as a function of joint angle for the knee flexors and knee extensors (Equation 1):

$$T_\theta = \left(1 - k_2\left(\theta - \theta_{opt}\right)^2\right).T_0 \qquad \text{Eq1.}$$

where optimal angle (θ_{opt}), width (k_2) and peak isometric torque (T_0) were extracted from literature and used to calculate isometric torque production (T_θ) at 10° intervals throughout the joint range of motion (flexion: 90°; extension: 85°). To simulate submaximal torque production, random noise (0-10Nm) was subtracted from the torque data at each measurement site to create 100 torque-angle curves for each joint action. The effect of the number and location of multiple measurement angles was determined for all possible measurement combinations for a minimum of three joint angles up to the maximum available in the joint range (flexion: 10, extension: 9). Simulated annealing was used to optimise parameters θ_{opt}, k_2 and T_0 and minimise the unweighted unbiased RMS difference [1] between the simulated torque data and the joint torques calculated by the quadratic function. The percentage error between the original parameters derived from the literature and optimised parameter values was calculated for all joint torque-angle curves.

RESULTS AND DISCUSSION

The percentage error between optimised and original parameter values for θ_{opt}, k_2 and T_0 decreased as the number of measurement sites increased for both the knee flexors and knee extensors (Table 1). Larger percentage errors for knee flexion may be explained by the nature of the torque-angle profile, which is predominately ascending and flat, compared to that of the knee extensors which demonstrates a more acute ascending-descending curve. The shape of the torque-angle curve may also explain observably larger percentage errors in k_2, particularly for the knee flexors. Generally, smaller percentage errors were observed for combinations that included a measurement site nearest to the optimal angle, which was close to full extension for the knee flexors (0°) and near the mid-range for the knee extensors (60°). For the knee flexors, combinations consisting of measurement sites closest to the optimal angle (e.g., [0°, 10°, 20°]) resulted in small errors in T_0 and θ_{opt}. Such combinations, however, resulted in larger errors in k_2 compared to combinations which spanned more of the joint range (e.g., [0°, 50°, 80°]). For the knee extensors, combinations consisting of measurement sites closest to the optimal angle (e.g., [60°, 70°, 80°]), or of purely ascending (e.g., [20°, 30°, 40°]) or descending (e.g., [80°, 90° ,100°]) sites exhibited larger errors across all parameters.

Table 1. Mean (±SD) percentage error between optimised and original parameter values across measurement combinations

	Number of measurement sites			
	3	5	7	Max
	Knee Flexion			
T_0	6.1 ± 3	4.5 ± 1.1	3.9 ± 0.7	3.9
θ_{opt}	7.9 ± 2	4.9 ± 1.4	3.7 ± 0.7	3.4
k_2	57 ± 31	23 ± 7.7	16 ± 3.5	14
	Knee Extension			
T_0	3.0 ± 1.3	2.1 ± 0.4	2.1 ± 0.2	1.9
θ_{opt}	0.7 ± 0.9	0.1 ± 0.1	0.1 ± 0.0	0.1
k_2	8.7 ± 7.9	2.6 ± 1.2	2.0 ± 0.4	2.4

T_0 = peak isometric torque (Nm), θ_{opt} = optimal angle (°) and k_2 = width

CONCLUSIONS

More accurate predictions of the torque-angle relationship should be expected for protocols with more measurement sites. The magnitude of this effect, however, decreases exponentially such that measuring all available sites may not be necessary. Furthermore, the strategy of measurement site selection can increase measurement accuracy. Practitioners should, therefore, consider the research question, muscle group under investigation and practical constraints when formulating an experimental protocol.

REFERENCES

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