

KNEE AND ANKLE JOINT MOMENT-ANGLE RELATIONSHIPS OF MULTI-JOINT LEG EXTENSION

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INTRODUCTION

The force-length-relation ($F-l-r$) is an important property of skeletal muscle to characterise its function, whereas for *in vivo* human muscles, moment-angle relationships represent the maximum muscular capacity as a function of joint angle. However, since *in vivo* force/moment-length/angle data is only available for rotational single joint movements the purpose of the present study was to identify ankle and knee joint moment-length/angle relationships ($M-l-r$) of maximal voluntary multi-joint leg extension.

METHODS

Experiments were carried out on 18 moderately active male subjects (30 ± 6.3 years of age) without any neuromuscular disorders or injuries at the lower extremity. To assess their $M-l-r$ subjects performed 3 sets of 8 maximum voluntary isometric contractions in a seated leg press dynamometer, each at different joint angles. Joint angle configurations were changed in steps of 10° knee angle from 30° - 100° knee flexion, which resulted in $-8.3 \pm 2.6^\circ$ (30° knee flexion) to $23.1 \pm 2.4^\circ$ dorsal extension (100° knee flexion).

External reaction forces exerted on the leg press were measured separately for each leg by a custom build force plate with 3-component force sensors (KISTLER, CH), and VICON MX-3 Motion-System (Oxford Metrics, UK) served for measuring lower extremity kinematics. Capturing frequency and sampling rate for analogue data was 240 Hz. Kinematic measurements and force recordings were synchronised by software. Joint moments in knee and ankle joint were calculated by the methods of inverse dynamics. To account for inertial properties an anthropometrical model was scaled individually to weight and body height by linear regression [1] and was adjusted according to [2].

RESULTS AND DISCUSSION

For the knee joint we found an ascending-descending $M-l-r$ with a maximum mean torque of 281.2 ± 47.9 Nm, occurring at an optimum knee angle of 50° knee flexion. Mean passive knee torques did not exceed 6.1 ± 6.8 Nm. From $-8.3 \pm 2.6^\circ$ to $5.0 \pm 2.3^\circ$ dorsal extension the $M-l-r$ of the ankle joint showed a plateau region with a maximum mean torque of 218.5 ± 29.8 Nm. For ankle angles $> 5.0^\circ$

dorsal extension, torques decreased to 130.3 ± 25.5 Nm at $23.1 \pm 2.4^\circ$ dorsal extension. Again, passive torques up to 12.3 ± 4.8 Nm didn't influence the ankle $M-l-r$ very much.

The characteristics of the $M-l-r$ for the knee joint closely match the corresponding relationship obtained during rotational knee extension. However, in comparison to many results from single joint testing reported in literature [3] we observed a 10° -shift of optimum knee angle towards knee extension. In contrast, the $M-l-r$ of the ankle joint vastly differed from relationships obtained in single joint plantar flexion experiments, which revealed the plantar flexors acting on the ascending limb of the $F-l-r$ [4]. Moreover, maximum mean torque of 218.5 ± 29.8 Nm exceeds single joint strength of plantar flexor muscles.

Concerning the ankle joint, we suggest the described differences resulting from the simultaneous activation of the knee extensor and plantar flexor muscles during multi-joint leg extension, which allow the biarticular m. gastrocnemius to develop more force. This gain in force is proposed to be due to an active bearing effect caused by the knee extensor muscles, an idea that is also supported by modeling, which revealed a significant correlation ($r = .832$) between the knee joint $M-l-r$ and the bearing effect.

CONCLUSIONS

From these findings we conclude that muscle function may differ between single joint and multi-joint tasks. However, in order to test this hypothesis we currently conduct follow-up experiments, where the same subjects perform single joint tests at identical angle configurations as used in this study. In case of verification, our findings should be considered for ergonomic and sports optimisation as well as for modelling and simulation of human movement.

REFERENCES

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Table 1: Mean (\pm SD) knee and ankle joint torque as a function of knee flexion and dorsal extension.

Torque (Nm)	Angle configurations of knee/ankle joint (deg)							
	30/-8.3	40/-4.3	50/0.9	60/5.0	70/9.4	80/14.4	90/19.9	100/23.1
Knee Joint	183.1 \pm 60.9	248.4 \pm 39.1	281.2 \pm 47.9	256.2 \pm 49.0	219.9 \pm 38.3	182.8 \pm 29.9	158.5 \pm 29.0	149.6 \pm 24.4
Ankle Joint	204.9 \pm 61.3	211.0 \pm 45.5	218.5 \pm 29.8	217.8 \pm 36.9	195.9 \pm 33.0	165.0 \pm 32.0	142.8 \pm 28.1	130.3 \pm 25.5