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A COMPARISON OF PLANTAR FLEXION TORQUE WITH AND WITHOUT THE TRICEPS SURAE

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Torque generated about the ankle joints during maximum isometric contraction of the plantar flexor muscles was measured on a subject 4 months after unilateral excision of the entire triceps surae. Resulting torque output on the operated limb was 327 kg-cm, or 38 per cent of the 871 kg-cm total for the sound limb.

Key words: ankle joint; exertion; muscles; muscle contraction; biomechanics

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The opportunity to measure and compare the torque output of the plantar flexor muscles with and without the triceps surae rarely presents itself. Although the importance of the gastrocnemius-soleus muscle group in producing forceful plantar flexion is well recognized, we were unable to find references to comparative measurements of this nature.

The purpose of this study is to quantitate the effect of the surgical excision of the gastrocnemius and soleus muscles on the torque generated about the ankle joint during maximum isometric contraction of the plantar flexor muscles of the sound and operated limb of one patient.

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METHOD

A 30-year-old female with clear-cell sarcoma (Enzinger 1965) of the Achilles tendon had surgical excision of the entire gastrocnemius-soleus muscle group. The remaining leg structures were left intact.

The patient began partial weightbearing with crutches 3 days postoperatively and began to walk without assistance 3 weeks after surgery. There was no clinical evidence of tumor recurrence, and the subject had been ambulatory and leading an active life life for 4 months when the torque measurements were made.

During these measurements, the subject was supine with her feet over the edge of the testing table and her ankles in the 90-degree, or neutral, position. She held on to the edges of the table and also was stabilized securely on the superior aspect of the shoulders.

A cuff was placed around her metatarsal heads, and a cable with an attached Liebow® tensiometer was fastened to the cuff with the cable perpendicular to the long axis of her foot. She made two attempts at maximum isometric plantar flexion on both the sound and the operated limbs with 1–½ minute rest periods between attempts. Her torque output was calculated as the product of the maximum tensiom-

Table 1. Calculated potential torque of the plantar flexor muscles

Muscle	Product of physiological cross section (cm^2) and absolute muscle force (3.9 kg/cm^2)	Lever arm (cm)	Potential torque (kg-cm)	Theoretical contribution to total torque	Contribution as calculated from subject
Gastrocnemius	89.7	4.8	430.6	80 %	62 %
Soleus	78.0	4.8	374.4		
Flexor hallucis longus	17.6	2.3	40.4		
Flexor digitorum longus	10.9	2.3	25.1		
Posterior tibialis	22.6	2.3	52.0	20 %	38 %
Peroneus longus	16.8	2.6	43.6		
Peroneus brevis	14.8	2.6	38.5		

eter reading and the distance from the center of the cuff to her ankle joint center (13.3 cm).

RESULTS AND DISCUSSION

The maximum isometric plantar flexion torque of the sound limb was 871 kg-cm and that of the operated limb, 327 kg-cm (38 per cent of that generated by the sound limb). The maximum contraction of both limbs occurred on the second attempt at maximum contraction, and the ratios of the torque produced by the two limbs were similar for both attempts.

The total force of muscle contraction cannot be measured directly in the intact body, but, assuming static conditions of equilibrium, the product of the transducer force value and the distance between the transducer attachment and the joint center is approximately equal to the product of the rotational component* of the force of the contracting muscles and their lever arms (the perpendicular distance between the action lines of the muscles and the joint centers).

As shown in Table 1, we calculated the hypothetical potential torque of each plantar flexor muscle as the product of its physiological cross section † (Fick 1911), a factor of 3.9 kg/cm^2 for absolute muscle force (Haxton 1944) and the lever arm lengths (Jergesen 1951).

The discrepancy between our actual measurements and the theoretical potential torque calculations (Table 1) may result from several factors. The remaining plantar flexor muscles of the operated limb of the patient may have hypertrophied postoperatively. General debilitation of the plantar flexor muscles of the sound limb during the preoperative and early postoperative period does not appear likely because her sound limb measurements were well above the normal torque measurements of Herman & Bragin (1967) and within the ranges of normal plantar flexor muscle force measurements of other investigators (Clarke 1950, Clarke et al. 1950, Liberson et al. 1962, Nordgren 1972, Tornvall 1963).

The discrepancy may also result from the physiological cross section sizes and force value used for theoretical torque calculations in Table 1. Since Fick's work in 1911, methods of determining the physiological cross-sectional area of a muscle have been developed which correct for the angle of insertion of the muscle fibers into the tendon and for the reduction in size found in cadaver limbs as opposed to live limbs. In addition, Haxton's value for absolute muscle force was based on *in vivo* force measurements which were matched with *in vitro* meas-

* The component of the resultant action line of the muscle which is perpendicular to the long axis of the foot.

† Cross sections of all of the muscle fibers at right angles to their long axes.

urements made from transducers attached on the point of insertion of the tendo calcaneus. His experimental design did not account for the torque generated by the five plantar flexor muscles which do not attach to the calcaneus, since he considered that these muscles are at an overwhelming mechanical disadvantage due to the proximity of their tendons to the ankle joint axis.

In any event, our actual measurements and the calculated potential torque measurements confirm the importance of the triceps surae in the force of plantar flexion, and yet indicate that the torque generated by the remaining plantar flexor muscles should not be underestimated.

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