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Limited *in vivo* mechanical effects of intermuscular myofascial connections within rat anterior crural compartment

Based on:

Tijs C, van Dieën JH, Maas H (submitted). Limited in vivo mechanical effects of intermuscular myofascial connections within rat anterior crural compartment.

Abstract

Skeletal muscles of the rat anterior crural compartment are mechanically connected by epimuscular myofascial connections, but the relevance for mechanical muscle function *in vivo* is as yet unclear. We evaluated the net effect at the ankle joint of epimuscular myofascial connections between tibialis anterior (TA) and extensor digitorum longus (EDL) muscles in the rat (n=8) and determined which anatomical structures may mediate such epimuscular mechanical interactions. We assessed (i) the effect of knee angle (i.e. changes in EDL length and position relative to TA) and interactions of knee angle with fasciotomy and proximal EDL tenotomy on TA ankle moment and (ii) the effect of knee angle on TA and EDL ankle moment summation. Knee angle was varied between 60° and 130°. Ankle angle was kept constant (90°). TA and EDL were excited individually and simultaneously (TA&EDL). The mathematical sum of individual TA and EDL moments was compared with the moment exerted by TA&EDL to assess nonlinearity of ankle moment summation. Magnitude of TA ankle moment was not affected by knee angle, but frontal plane moment direction was. However, dissections indicated that this was not caused by the compartmental fascia or EDL length changes. Moment summation was nonlinear in magnitude (+1.1±1.1% mean±SD) and frontal plane direction. The latter was affected by knee angle and ranged from +0.2±0.3° at 60° to +1.1±0.6° at 130°. As the net effects found were very limited, we conclude that myofascial connections between muscles in the anterior crural compartment have limited mechanical relevance during normal movement.

Introduction

The myotendinous junction is the primary pathway for force transmission from the muscle via the tendon to the skeleton. Myofascial connections between a muscle's epimysium and surrounding structures can also transmit force (Huijing, 2009; Maas & Sandercock, 2010). Clear evidence has been provided by rat studies in which muscles were excited maximally and their tendons were severed from the skeleton to measure forces exerted onto them. Forces exerted at the tendon of a muscle kept at a constant muscle-tendon unit length were dependent on the neighboring muscle's length (Maas *et al.*, 2005; Meijer *et al.*, 2006; Huijing *et al.*, 2007; Rijkelijhuizen *et al.*, 2007; Huijing & Baan, 2008) or relative position (Maas *et al.*, 2004). Although several of these imposed changes were beyond those found during normal movement, sizable epimuscular myofascial force transmission between rat ankle plantar-flexion muscles was recently reported for a physiological range of muscle lengths and relative muscle positions (Bernabei *et al.*, 2015).

Epimuscular myofascial connections can evidently transmit force, but the relevance for the mechanical function *in vivo* remains unclear. Results indicating limited relevance have been reported in studies wherein the muscular compartment was kept as intact as possible and joint rotations were applied to impose changes in muscle length and relative position comparable with those found during normal movement. Ankle moments exerted by soleus muscle in rats (Tijs *et al.*, 2015a) and cats (Maas & Sandercock, 2008) were not affected by length changes of passive synergists, as imposed by changes in knee angle. Considering previous results (Bernabei *et al.*, 2015), epimuscular myofascial force transmission is present between soleus and gastrocnemius muscles, but because these muscles have largely comparable lines of action (Tijs *et al.*, 2014), intermuscular force transmission will not be reflected in their moment vectors.

Muscles within the anterior crural compartment have more distinct line of actions. While the mono-articular tibialis anterior (TA) exerts an ankle inversion moment, the poly-articular extensor digitorum longus (EDL) exerts an ankle eversion moment. Hence, the net effect of epimuscular myofascial force transmission at the ankle joint may be more pronounced.

The main purpose of the present study was to evaluate the *in vivo* mechanical relevance of epimuscular myofascial connections between TA and EDL muscles in

the rat. Therefore, we assessed the effects of knee angle (i.e. proximal EDL length changes and not of TA) on (i) TA ankle moment and on (ii) TA and EDL ankle moment summation. A secondary purpose was to assess which anatomical structures mediate such epimuscular mechanical effects, to which end interaction effects of knee angle with fasciotomy and proximal EDL tenotomy on TA ankle moment were assessed.

Materials & Methods

Animals

Data were obtained from 8 male Wistar rats (body mass: 313.4 ± 10.5 g, mean \pm SD). All procedures were in agreement with the guidelines and regulations concerning animal welfare and experimentation set forth by Dutch law, and approved by the Committee on Ethics of Animal Experimentation at the Vrije Universiteit Amsterdam (Permit Number: FBW 11-02).

According to standard procedures in our laboratory (Maas *et al.*, 2001), intraperitoneally injected urethane was used to deeply anesthetize the animals, such that reflexes were fully suppressed. To maintain a core temperature of approximately 37°C, rats were placed on an electrical heating pad. Saline solution was applied frequently to prevent dehydration of exposed tissues. At the end of the experiment, animals were euthanized with an overdose of intracardially-injected pentobarbital sodium followed by a double-sided pneumothorax.

Surgery

Skin and biceps femoris muscle of the left hindlimb were removed. Medial and lateral malleoli and origin of medial and lateral collateral ligaments were marked and used as axis of rotation of ankle and knee joints, respectively. The femur was partly exposed to allow attachment of a metal clamp. The peroneal nerve was dissected free for placement of a cuff electrode. The superficial peroneal nerve and all branches of the deep peroneal nerve distally to the cuff electrode were cut, except one of two branches innervating TA muscle (Fig. 4.1). Because we wanted to keep the anterior crural compartment intact, only the branch entering TA proximally could be excited via the cuff electrode.

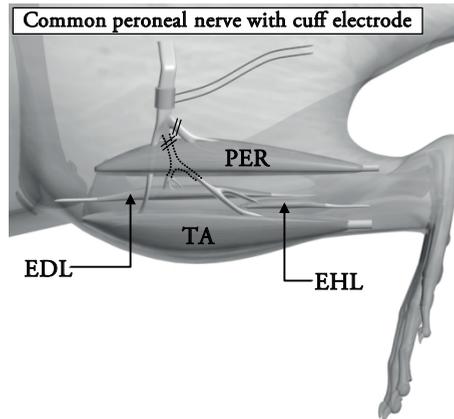


Figure 4.1. Schematic view of branches of the common peroneal nerve. To excite TA muscle, a cuff electrode was placed around the common peroneal nerve proximally to the bifurcation into the deep peroneal nerve (to TA,EDL,EHL) and branches of the superficial peroneal nerve (to PER). Nerve branches innervating PER, EDL, EHL and distal TA were transected (solid black lines), leaving only the branch entering TA proximally intact. PER: peroneus. EDL: extensor digitorum longus. TA: tibialis anterior. EHL: extensor hallucis longus. For clarity, nerves innervating TA and EHL are displayed on top of the EDL muscle.

To excite EDL, bipolar intramuscular wire electrodes were inserted near the motor endplates located in the distal region. Because EDL muscle belly is accessible only after a full longitudinal fasciotomy of the anterior crural compartment (Huijing *et al.*, 2003; Maas *et al.*, 2005), this was performed after the first set of measurements (see experimental protocol below).

Fixation in experimental apparatus

The left hindlimb was secured to the experimental set-up (for photographic overview see Tijss *et al.*, 2014) by clamping the femur and attaching the foot to a 6 degrees-of-freedom load cell (Mini40-E, ATI, Apex, NC, USA). As EDL tendons insert onto the distal phalanx of digits II-V, the digits were secured in a neutral (180°) position. Ankle and knee joints were aligned with the set-up's rotational axes and their position relative to the origin of the load cell was measured using rulers integrated in the set-up.

Experimental protocol

TA muscle was excited by supramaximal stimulation of the common peroneal nerve (amplitude: 0.3-0.4 mA, frequency: 100 Hz, pulse width: 100 μ s) via the bipolar cuff electrode connected to a constant current source (Digitimer DS3, Digitimer Ltd., Hertfordshire, England). Note that only the proximal TA nerve branch was excited. Based on existing data (Huijing & Baan, 2001a; Maas *et al.*, 2001) we estimated TA isometric force to be \sim 6N at 90° ankle angle. Assuming a dorsi-flexion moment arm of \sim 3.5 mm at this angle (Johnson *et al.*, 2008), estimated maximum TA ankle moment was 21 mNm. Combining this with our data (TA moment 18.7 \pm 3.4 mNm; see Results) indicates that approximately 90% of TA muscle fibers was excited in the present study. EDL muscle was excited submaximally via the intramuscular electrodes (amplitude: 0.7-2.0 mA, frequency: 100 Hz, pulse width: 100 μ s). A pilot experiment revealed that approximately 60% of maximum ankle moment exerted by EDL muscles fibers was exerted when stimulating intramuscularly compared to supramaximal nerve stimulation.

To assess the extent of mechanical interactions between TA and EDL muscles within physiological ranges, TA was kept at a constant muscle-tendon unit length by keeping the ankle angle constant, and the knee angle was varied to change EDL length and position relative to TA. As knee extension decreases the length of EDL and not of TA, the stiffness of epimuscular myofascial connections between these muscles may change, which was expected to affect the extent of intermuscular mechanical interaction. Note that, in contrast to some reports (Johnson *et al.*, 2008), in the rat EDL spans the knee joint (Greene, 1935; Hildebrand *et al.*, 1991; Maas *et al.*, 2004). Changes in knee angle were applied in two experimental conditions: (i) TA was activated while EDL remained passive. Effects of knee angle on magnitude and direction of TA ankle moment were assessed; (ii) Both TA and EDL were activated. Differences between ankle moment exerted during simultaneous excitation of TA and EDL (TA&EDL) and the sum of joint moments exerted by each muscle individually were assessed. If epimuscular myofascial connections between these muscles are of mechanical significance, such nonlinear summation will be knee angle dependent.

Previous studies found sagittal plane knee angles between 55° and 125° in the rat during locomotion (Gruner & Altman, 1980; Gruner *et al.*, 1980; Bauman & Chang, 2010). In agreement with these values, we rotated the knee in the sagittal

plane from 60° to 130° or vice versa (alternated between experiments) in steps of 10°, while sagittal plane ankle angle was kept constant at 90°. For both joints, the angles in the other two planes were kept at 0°. At each designated knee angle, the lower hindlimb was compressed (approximately 5N) to ensure minimal compliance in the ankle and knee joints.

During the experiment, surgical interventions were performed resulting in three stages of dissection: (I) intact compartment; (II) after full longitudinal fasciotomy; (III) after proximal EDL tenotomy. For stage I, TA muscle was excited exclusively (300ms). For stage II, two stimulation protocols were performed subsequently for each knee angle. First, TA and EDL muscles were stimulated separately (TA: 300ms, EDL: 400ms). Second, TA and EDL muscles were both stimulated, but with trains of different length (EDL for 400ms followed after 200ms by TA for 200ms). The order of the stimulation protocols was alternated between experiments. For stage III, TA and EDL were excited separately (TA: 300ms, EDL: 400ms) at each knee angle to assess effects of proximal EDL tenotomy on isometric TA and EDL ankle moments. Two minutes rest periods were allowed between stimulation protocols. Video recordings (PANASONIC HC-V720, 1920x1080 pixels, resolution 1 pixel ~ 0.05 mm) were made to assess the proximal EDL tendon gap, which emerged when EDL contracted after proximal EDL tenotomy.

Data analysis

For each knee angle, ankle moments were calculated around three axes (axis perpendicular to the transverse plane: inversion(+)/eversion; axis perpendicular to the sagittal plane: plantar-flexion/dorsi-flexion(+); axis perpendicular to the frontal plane: external rotation(+)/internal rotation) from forces and moments measured by the load cell using inverse static analysis (Tijs *et al.*, 2014). Around each axis, ankle moments were assessed by calculating the mean over 50-ms time windows before (passive) and during individual TA and EDL excitation as well as during simultaneous TA and EDL (TA&EDL) excitation. To obtain active TA, EDL and TA&EDL ankle moments, the passive moment was subtracted from the ankle moment during muscle contraction.

TA, EDL and TA&EDL ankle moments around each axis were used to calculate the magnitude of the 3D ankle moment vector and the direction of the

projection of the 3D vector in the three anatomical planes. For TA vectors in the transverse and frontal planes, the angle relative to the dorsi-flexion moment axis (α and β , respectively) was calculated. For TA vectors in the sagittal plane, the angle relative to the inversion moment axis (γ) was calculated (Fig. 4.2A).

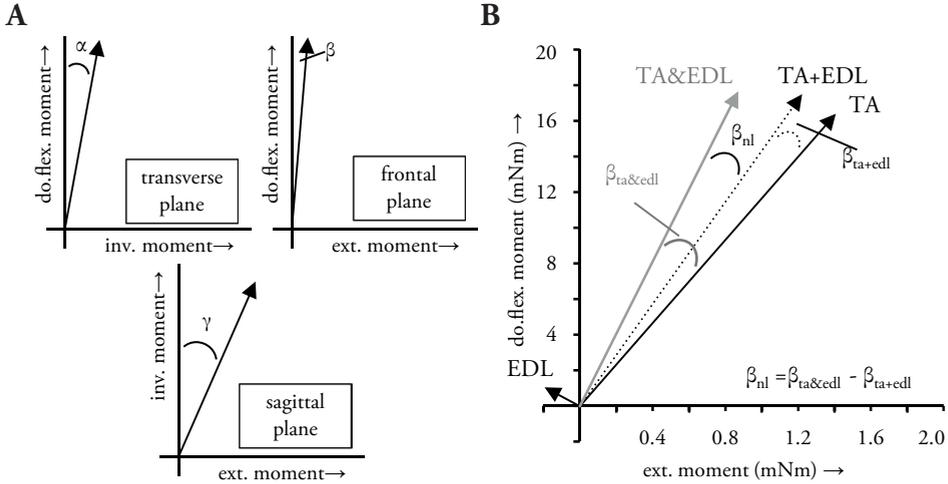


Figure 4.2. Vector directions of exerted ankle moments. (A) For calculating TA vector direction in the transverse and frontal planes, the angle between the TA vector and the dorsi-flexion moment axis was calculated (α and β , respectively). In the sagittal plane, the angle between the TA vector and the inversion moment axis (γ) was calculated. Do.flex.: dorsi-flexion, inv.: inversion, ext.: external rotation. (B) Nonlinear summation of vector directions in the frontal plane. Vector direction of individual TA and EDL ankle moments (black solid lines), of the summed ankle moment exerted on excitation of TA and EDL individually (TA+EDL, black dotted line), and of the ankle moment exerted on simultaneous excitation TA and EDL (TA&EDL, grey solid line). For calculating nonlinear direction summation in the frontal plane (β_{nl}), the angle between TA and TA+EDL vectors (β_{ta+edl}) was subtracted from the angle between TA and TA&EDL ($\beta_{ta\&edl}$). Positive value of β_{nl} indicates that the vector direction of TA&EDL is directed more towards the moment direction of EDL than predicted based on the mathematical sum. Note that, for clarity, the ranges of both axes are not equal to each other. The data in this example were obtained with the ankle and knee angle kept at 90° and 130° , respectively.

Nonlinear magnitude summation was assessed by subtracting the mathematical sum of TA and EDL ankle moments (TA+EDL) from the TA&EDL magnitude (Tijss *et al.*, 2014). This was then normalized ($\%M_{nl}$) relative to the magnitude of TA+EDL. Nonlinear direction summation was assessed for each of the three anatomical planes (transverse plane: α_{nl} ; frontal plane: β_{nl} ; sagittal plane: γ_{nl}) by calculating the enclosed angle between the moment vector of TA+EDL and TA&EDL (Fig. 4.2B for a frontal plane example).

Prior to and after each stage of dissection, control measurements were performed at a knee and ankle angle of 90°. Any changes in muscle conditions that could affect interpretation of the data were assessed.

Statistics

To test for effects of knee angle on TA ankle moment, one-way repeated measures ANOVAs (SPSS 20, IBM, USA) with 'knee angle' as independent factor were applied. Two-way repeated measures ANOVAs with 'knee angle' and 'dissection' as independent factors were applied to test for interaction effects between these factors on TA ankle moment. In addition, two levels of 'dissection' as independent factor ('intact' vs 'fasciotomy' and 'fasciotomy' vs 'tenotomy') were applied to perform planned comparisons for a main effect of dissection on TA moment. One-sample t-tests were used to test if nonlinear summation averaged across knee angles was significantly different from zero. To test for effects of knee angle on nonlinear summation of TA and EDL ankle moments, one-way repeated measures ANOVA with 'knee angle' as independent factor was applied. Paired t-tests were performed to assess effects of proximal EDL tenotomy on EDL ankle moment and to evaluate any changes in TA and EDL muscle conditions due to dissection and/or preceding muscle contractions. Greenhouse Geisser correction was used if the assumption of sphericity was violated. Level of significance was set at $p \leq 0.05$.

Results

Effects of knee angle on 3D ankle moment of TA muscle

Knee angle (i.e. proximal EDL length changes) did not affect ($p=0.057$) the magnitude of the 3D TA ankle moment (average across knee angles: 18.7 ± 3.4 mNm, Fig. 4.3). ANOVA indicated no interaction effect between dissection and knee angle ($p=0.930$), but fasciotomy decreased TA moment to an average of 17.2 ± 3.4 mNm ($p < 0.001$, Fig. 4.3). Following proximal EDL tenotomy, TA moment decreased further to an average of 16.8 ± 3.6 mNm ($p=0.037$). This change, however, was not significant ($p=0.231$) if corrected for the observed decrease in the control measurements (-0.3 ± 0.3 mNm, $p=0.023$).

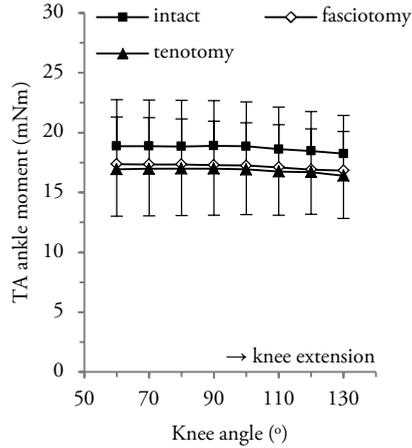


Figure 4.3. Effects of knee angle on the magnitude of TA ankle moment. Effects of dissection (intact ■; fasciotomy ◊; tenotomy ▲) on the magnitude of TA ankle moment plotted as a function of knee angle. Means±SD are shown (n=8).

Knee angle did affect TA moment vector direction, but only in the frontal plane (β , $p=0.035$, Fig. 4.4B). Extending the knee from 60° to 100° increased the direction from $\beta=-4.1\pm 1.8^\circ$ to a peak angle of $\beta=-6.5\pm 2.9^\circ$. Thereafter, the angle decreased to $\beta=-3.8\pm 2.9^\circ$ at 130° . ANOVA indicated neither a main effect of dissection on vector direction (transverse plane: $p=0.094$, Fig. 4.4A; frontal plane: $p=0.147$; sagittal plane: $p=0.304$, Fig. 4.4C) nor interaction effects between dissection and knee angle (transverse plane: $p=0.763$, frontal plane: $p=0.994$, sagittal plane: $p=0.973$).

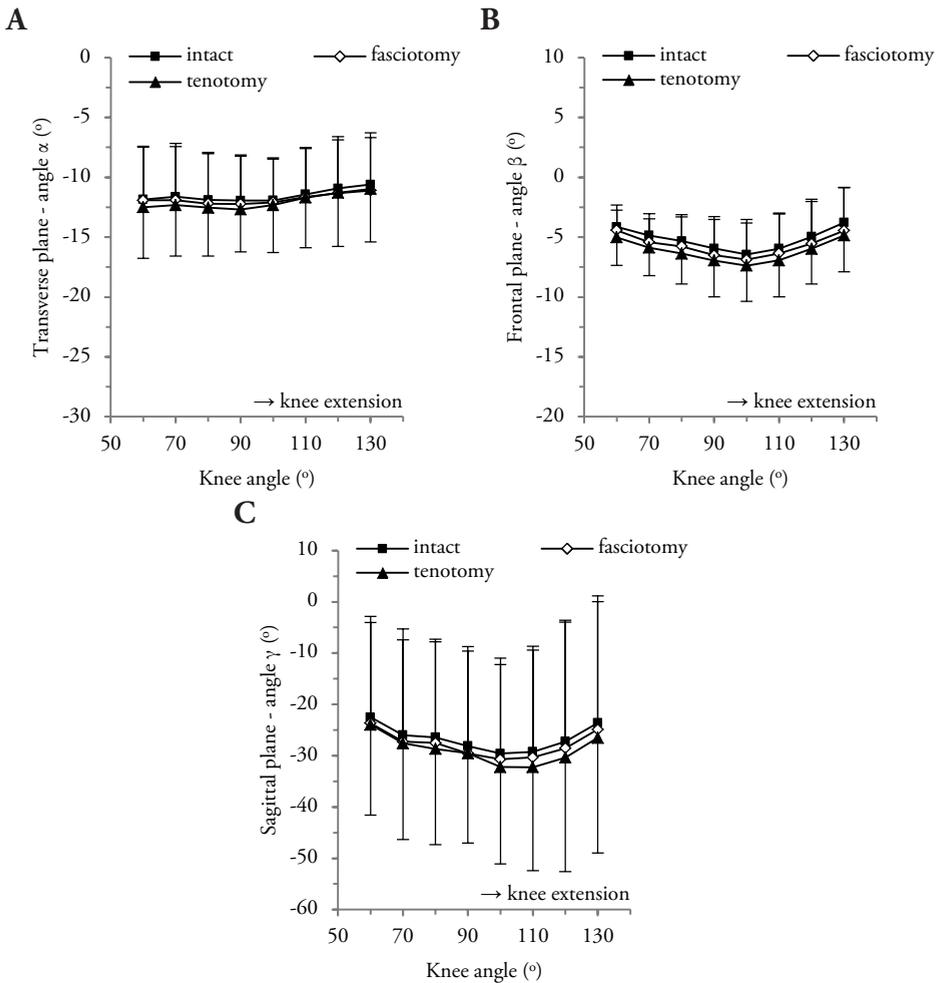


Figure 4.4. Effects of knee angle on the direction of TA ankle moment. Effects of dissection (intact ■; fasciotomy ◇; tenotomy ▲) on the direction of TA ankle moment in the transverse (A), frontal (B) and sagittal (C) planes plotted as a function of knee angle. Means \pm SD are shown (n=8).

Summation of TA and EDL ankle moments

A small but significant ($p=0.004$) nonlinear magnitude moment summation of $+1.1\pm 1.1\%$ ($+0.2\pm 0.2$ mNm, $p=0.003$) averaged across all knee angles was found (Fig. 4.5A). Knee angle did not affect the extent of this nonlinearity ($p=0.438$). Nonlinear summation of moment direction (Fig. 4.5B) was found only in the frontal plane (β_{nl} , $p=0.006$) and was, in this case, knee angle dependent ($p<0.001$). In that plane, nonlinear direction summation ranged from $\beta_{nl}=+0.2\pm 0.3^\circ$ at 60° to $\beta_{nl}=+1.1\pm 0.6^\circ$ at 130° . The positive summation angle indicates that the vector direction in the frontal

plane during simultaneous excitation of TA and EDL is directed more towards the EDL vector than predicted based on the mathematical sum. In the transverse and sagittal planes, nonlinear direction summation was not significantly different from zero ($p=0.203$ and $p=0.684$, respectively) and not knee angle dependent ($p=0.277$ and $p=0.594$, respectively).

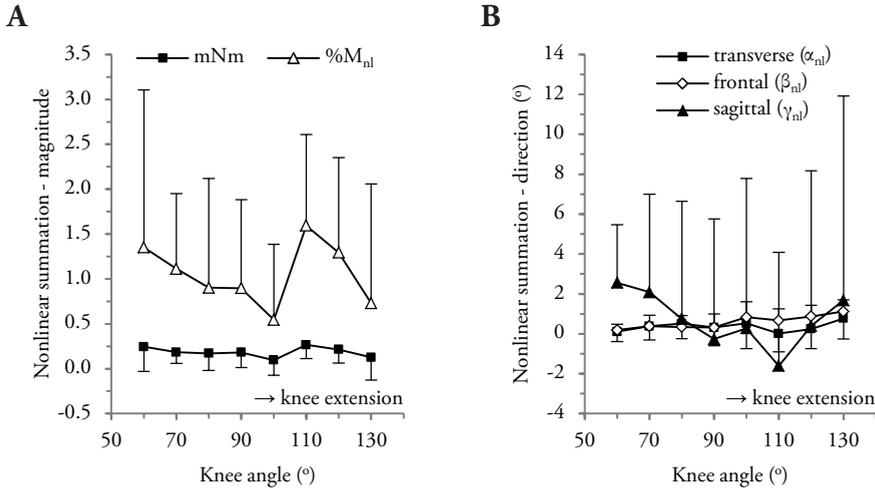


Figure 4.5. Effects of knee angle on TA and EDL ankle moment summation. (A) Nonlinear magnitude summation (linear summation= 0°), shown as absolute values (mNm) and relative to the mathematical sum (TA+EDL) of the ankle moments exerted by individual TA and EDL muscles ($\%M_{nl}$). Positive values indicate a higher ankle moment exerted on simultaneous excitation of TA&EDL than the mathematical sum of the individual TA and EDL ankle moments. (B) Nonlinear direction summation (linear summation= 0°) in the transverse (α_{nl} , ■), frontal (β_{nl} , ◇) and sagittal (γ_{nl} , ▲) planes plotted as a function of knee angle. Means \pm SD are shown (n=8).

Effects of proximal EDL tenotomy on the magnitude of EDL ankle moment

Proximal EDL tenotomy decreased (Fig. 4.6, $p<0.001$) EDL ankle moment by 1.4 ± 0.2 mNm (by $67.1\pm 4.3\%$). After tenotomy, a tendon gap of 5.7 ± 0.7 mm was found during contraction. This shortening of EDL muscle explains, at least partially, the decrease in ankle moment. Despite severing its origin, a substantial moment was still exerted on excitation of EDL (0.7 ± 0.1 mNm). This indicates that connective tissue linkages prevented EDL muscle fibers to shorten to active slack length.

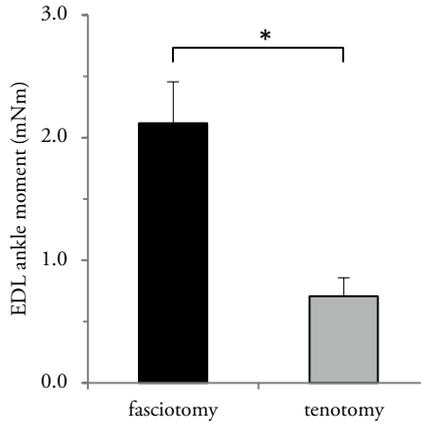


Figure 4.6. Effects of proximal EDL tenotomy on EDL ankle moment. EDL ankle moment following fasciotomy (note that EDL could be excited only after fasciotomy, see methods) and after tenotomy are shown. Knee and ankle angle were kept at 90°. * $p < 0.001$. Means \pm SD are shown (n=8).

Discussion

The main findings of the present study are that (i) TA ankle moment was not affected by changes in knee angle, which involves proximal length changes of passive EDL; (ii) although summation of TA and EDL ankle moments was nonlinear, nonlinearity was only minimally affected by knee angle; and (iii) EDL did exert a substantial moment after its origin was severed, which confirms the existence of strong myofascial connections between EDL and its surroundings.

Effects of epimuscular myofascial connections on TA ankle moment

The existence of epimuscular connective tissues between muscles in the anterior crural compartment of the rat hindlimb and their surrounding structures have been investigated extensively, which has been confirmed in the present study. Force exerted at the tied distal tendons of TA and extensor hallucis longus (EHL) increased when the position of EDL, kept at a constant muscle-tendon unit length, was moved from a distal to a proximal position relative to TA and EHL (Maas *et al.*, 2004). Distal TA and EHL force decreased when EDL was lengthened distally (Huijing & Baan, 2003, 2008). These conditions were beyond physiological ranges considering that, during ankle joint movements the length of TA, EDL and EHL change to a similar extent. Changes in knee angle, however, does result in EDL length changes

exclusively and, hence, in relative muscle displacements. In contrast to distal length changes, lengthening EDL proximally was reported not to affect distal TA and EHL forces (Huijing & Baan, 2001*a*, 2003, 2008; Huijing *et al.*, 2003). This is in agreement with the results of the present study, despite the fact that we activated TA only instead of the whole synergistic muscle group. Therefore, the lack of epimuscular myofascial force transmission can most likely not be explained by the absence of co-activation (see next section on co-activation). These results suggest that intermuscular connections in the anterior crural compartment are organized in such a way that its net effect does not influence the mechanical function of neighboring muscles when the range of relative muscle displacements is within physiological limits.

Even though fasciotomy did not affect the relationship between knee angle and TA ankle moment, it decreased the moment magnitude. This is in agreement with a decrease in TA force following fasciotomy observed in dogs (Garfin *et al.*, 1981). Also in rats, it has been found that fasciotomy decreased muscle force (Huijing & Baan, 2001*b*; Smeulders *et al.*, 2002). Such effects of fasciotomy have been attributed not only to extramuscular myofascial connections (Huijing & Baan, 2001*b*), but also to a decrease in intramuscular pressure (Garfin *et al.*, 1981). In the present study, however, we cannot distinguish between these mechanisms.

We found a small effect of knee angle on TA moment direction. The results following tenotomy proved that this change was not caused by proximal EDL lengthening. Thus, other factors should be involved. Knee extension causes displacement of the sciatic nerve in proximal direction in humans (Ellis, 2012) and, hence, also of the common peroneal nerve. This may have resulted in changes of myofascial loads exerted by the neurovascular tract onto TA. In addition, tibiofemoral contact points may change as a function of knee angle due to the fact that the knee joint does not act as a perfect hinge (Hildebrand *et al.*, 1991).

Effects of epimuscular myofascial connections on TA and EDL ankle moment summation

Co-activation of nearby muscles has been suggested to stiffen connective tissue linkages and, hence, facilitate epimuscular myofascial force transmission (Maas & Sandercock, 2008). To date, however, there exists no evidence supporting this hypothesis (Maas & Huijing, 2009; Tijs *et al.*, 2015*a*). In the present study, we did

find effects of knee angle on nonlinear direction summation when both TA and EDL were active. Knee extension (i.e. proximal decrease in EDL length) increased nonlinear direction, however, the increase was very small (-1°). Nonlinearity was rather constant between 60° and 90° , and increased between 90° and 130° . This suggests connective tissue linkages were substantially tensioned only at more extended knee angles. Note that knee joint angle does generally not exceed 90° during rat locomotion (Canu & Garnier, 2009; Bauman & Chang, 2010), indicating a minimal functional relevance of this nonlinearity.

We found limited positive nonlinear magnitude summation (+1%). Positive nonlinearity has previously been found between muscle fibers within the same muscle, but only when a small number of motor units was excited (Powers & Binder, 1991; Sheard *et al.*, 1999). During excitation of motor units individually, not all force exerted by the active fibers is transmitted to the tendon, but also to neighboring passive fibers that are tensioned by this force. During simultaneous excitation of these motor units, force can be transmitted to the tendon more efficiently (Sheard *et al.*, 1999). A similar mechanism may have occurred via epimuscular myofascial pathways between TA and EDL muscle fibers in the present study. Alternatively, positive nonlinear summation may have been the result of an increased moment arm of TA and/or EDL during co-contraction, as muscle contraction can increase muscle moment arm (Maganaris *et al.*, 1998, 1999; Akagi *et al.*, 2012). In addition, an increase in compartmental pressure due to co-activation could have increased muscle force, since these factors are correlated (Garfin *et al.*, 1981).

Functional implications

The results of the present study are relevant not only for constructing biomechanical models, but also for functional electrical stimulation (FES) to control limb movements. Both applications assume muscles to be fully independent actuators. A recent study (Jarc *et al.*, 2013), in which endpoint forces were assessed for several combinations of rat hindlimb muscles, found close to linear summations of muscle force vectors. The results of the present study are in agreement with that study.

TA and EDL have opposite mechanical effects at the ankle joint in the frontal plane (TA: inversion, EDL: eversion). The very limited net effects of epimuscular myofascial force transmission at the joint level allows these muscles to act

independently. This may be advantageous for accurate control of ankle joint stability. This seem to be in contrast to a recent study showing that lengthening gastrocnemius and plantaris muscles proximally, simulating knee extension, increased the force exerted at the distal tendon of soleus muscle significantly (Bernabei *et al.*, 2015). However, because ankle plantar-flexors have largely comparable lines of action (Tijs *et al.*, 2014), the presence of myofascial force transmission will not affect the functional output at the joint. Recent studies (Maas & Sandercock, 2008; Tijs *et al.*, 2015a) did indeed found no effects of knee extension on soleus ankle moment. Even in the absence of mechanical effects at the joint level, force transmission between triceps surae muscles may serve as a mechanism to reduce local stresses by distributing stresses and strains over multiple muscles and tendons (Bojsen-Møller *et al.*, 2010).

Conclusion

We found very limited effects of proximal EDL length changes on the mechanical output effect of TA at the ankle joint. Therefore, we conclude that myofascial connections between muscles in the anterior crural compartment have limited mechanical relevance if synergistic length changes are within ranges that occur during normal movements.

Acknowledgements

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