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DIFFERENCES IN CONTRACTILITY BETWEEN PROXIMAL URETHRAL AND BLADDER MUSCLE BUNDLES OF THE FEMALE PIG

Aims of Study

Like the bladder, the urethral wall consists of different muscle layers. Female pig urethra contains circular and longitudinal smooth and striated muscle bundles [1]. With the aim to model the urethra, we compared the contractile properties of proximal urethral muscle to those measured in bladder smooth muscle. The force-length and the force-velocity relation were measured to characterise the muscle contractility by the isometric force and the unloaded shortening velocity.

Methods

We determined the force-length relation in 10 urethral muscle bundles (~2*0.5 mm) from the proximal urethra and 10 bladder muscle bundles from the serosal side of the bladder wall, cut from 4 different bladder-urethras. In 14 bundles (7 urethral and 7 bladder muscle bundles) the force-velocity relation was also determined using the stop-test. The bundles were electrically stimulated at a fixed length (l_{stop}) during which the force increased to an isometric value (F_{iso}). The time constant (τ) of the contraction was calculated using phase plots [2]. The force-length relation was measured by stepwise increasing l_{stop}. From the F_{iso}-l_{stop} relation, the optimum muscle force (F_{opt}) and the corresponding optimum muscle length (l_{opt}) were determined. Subsequently, the force-velocity relation was derived at l_{opt} by measuring force production at three different shortening velocities (v) of 50, 100 or 150 µm/sec for 2 seconds. This series was repeated once.

Results

In urethral muscle bundles, isometric force development revealed a fast and a slow component [3], whereas in bladder muscle bundles only a slow component was seen (figure 1, upper panel). We quantified these components using phase plots (lower panel) and derived in urethral muscle bundles two time constants ($\tau_{urethra\text{-}fast}$ = 0.6s ± 0.2s and $\tau_{urethra\text{-}fast}$ = 2.3s ± 0.7s) and in bladder muscle bundles only one ($\tau_{bladder}$ = 2.5s ± 0.5s). The fast and slow time constants found in urethral bundles were significantly different ($p<0.01$), but the slow time constant of urethral bundles was not significantly different ($p=0.44$) from that of bladder bundles (Wilcoxon signed ranks test). We plotted the force-length relation of urethral (open circles) and bladder (closed circles) muscle bundles as the normalized force (F_{iso}/F_{opt}) against the normalized length $(l_{start}-l_{opt})/l_{opt}$ of each bundle (figure 2, upper panel). On average, the length range of urethral muscle bundles was smaller than that of bladder bundles. Beyond the optimum length, the normalized forces remained at a plateau level in bladder muscle bundles, whereas in urethra a decrease was seen. To determine the force-velocity relation, we plotted for each muscle bundle the force production during shortening as a function of the normalized shortening velocities applied, v/l_{opt} (lower panel). A hyperbolic curve, similar to the Hill-curve, was fitted to these data points to derive the curvature (c) and the unloaded shortening velocity (v_{max}/l_{opt}) of urethral and bladder muscle bundle [3]. Compared to bladder, the curvature (c = 0.43 ± 0.16 versus 1.21 ± 0.26) was on average lower and the unloaded shortening velocity (v_{max}/l_{opt} = 0.26 ± 0.04 1/s versus 0.12 ± 0.01 1/s) higher in urethral muscle bundles.

Conclusions

In contrast to earlier findings [1], the two time constants found in female pig urethral muscle bundles suggest that at the level of the bladder neck, the proximal urethral wall may consist of striated muscle interwoven with smooth muscle [4]. Furthermore, the working range of urethral muscle is smaller than that of bladder muscle, but surprisingly, its unloaded shortening velocity is about 2 times higher. These findings are important in modelling the bladder and urethra complex.

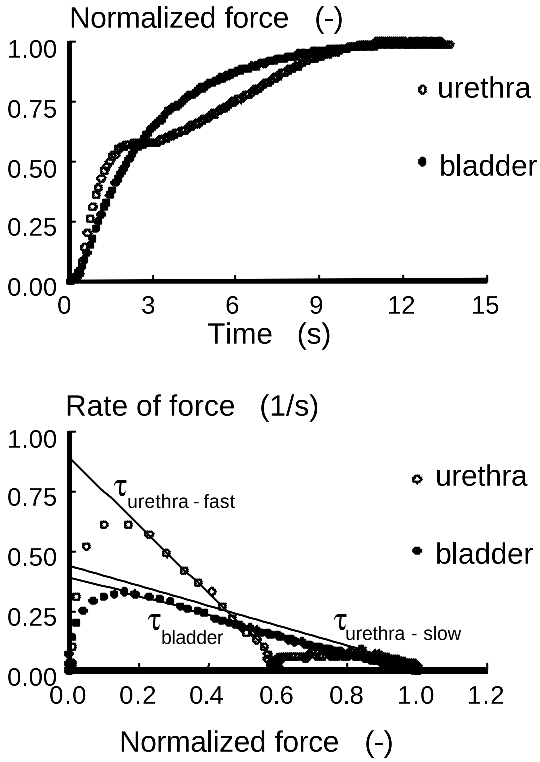

Figure 1 The upper panel shows an example of an isometric contraction in urethra and bladder muscle bundles at l_{opt}. In the lower panel, we plotted for both contractions the rate of force (dF/dt) against the force itself. The straight lines dominating the phase plots represent the time constants of the contractions.

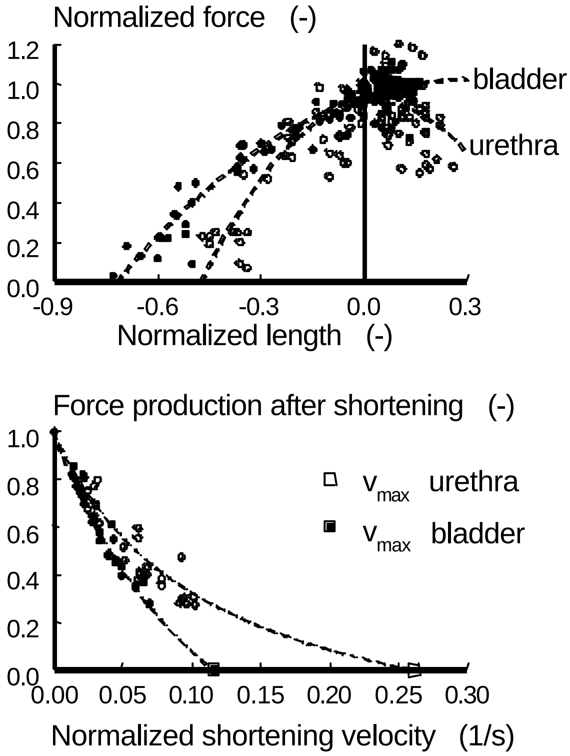

Figure 2 Upper panel shows the normalized forces (F_{iso}/F_{opt}) against the normalized muscle length ($(l_{start}-l_{opt})/l_{opt}$). A second order polynomial was fitted through the data points to visualize the length-force relation of urethral ($R^2 = 0.7$) and bladder ($R^2 = 0.9$) muscle bundles. Lower panel shows the force production during shortening against the 3 normalized shortening velocities applied v/l_{opt}. The two fitted curves intercept the horizontal axis at the unloaded shortening velocity, v_{max}/l_{opt}.

References

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