

Supplementary methods

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Energy storage, power output and work

Energy required for strike

The effects of water on the power requirements of the strike can be estimated as:

$$P_{\text{out}} = P_{\text{inertia}} + P_{\text{drag}} + P_{\text{accel}} \quad (1)$$

where P_{inertia} is the power to accelerate the appendage in a vacuum, P_{drag} represents drag forces, and P_{accel} represents the acceleration reaction.

P_{inertia} can be calculated as the product of the moment of inertia (I), angular acceleration ($\dot{\omega}$) and angular speed (ω) of the carpus/propodus/dactyl unit:

$$P_{\text{inertia}} = I\dot{\omega}\omega \quad (2)$$

The carpus/propodus/dactyl unit is approximately elliptical in cross-section, thus we calculated the moment of inertia along its length (H):

$$I = \pi\rho_s \int_0^H abh^2 dh \quad (3)$$

where ρ_s is the density of the limb segments, 1525 kg m^{-3} . We measured the semi-minor axis (a) and semi-major axis (b) along the radial length of the limb segments (h) yielding a moment of inertia equal to $8.9 \times 10^{-8} \text{ kg m}^2$.

Power due to drag was summed along the length of the appendage as follows:

$$P_{drag} = \frac{1}{2} \rho_w C_d \omega^3 \int_0^H ah^3 dh \quad (4)$$

At Reynolds numbers on the order of 10^5 , with the carpus/propodus/dactyl unit modelled as a cylinder, the coefficient of drag (C_d) is approximately equal to 1^{1,2}. The density (ρ_w) of saltwater at 30° C is $1.02 \times 10^3 \text{ kg m}^{-3}$.

Power due to the acceleration reaction was calculated as:

$$P_{accel} = \frac{C_a \rho_w}{\rho_s} P_{inertia} \quad (5)$$

At Reynolds numbers on the order of 10^5 , with the carpus/propodus/dactyl unit modelled as a cylinder, the added mass (C_a) is approximately equal to 1^{1,2}.

At an angular speed of a typical strike (675 rad s^{-1}), the peak power outputs were: $P_{inertia} = 201 \text{ W}$, $P_{accel} = 135 \text{ W}$, and $P_{drag} = 39 \text{ W}$. Thus, for a typical strike, the total sum of power requirements equals 374 Watts, or $4.7 \times 10^5 \text{ W kg}^{-1}$ muscle, which far exceeds the power output of the fastest known muscles³⁻⁵. Therefore, we next examined the contribution of strain energy stored in the apodeme and isometrically contracted extensor muscle to the work required by this movement.

Energy storage in muscle and apodeme

We estimated the strain energy stored in the isometrically contracted lateral extensor muscle using a combination of published and measured values. We used published values of sarcomere length (λ) in the *Hemisquilla* stomatopod lateral extensor muscle ($7.8 \mu\text{m}$)⁶, the maximal isometric stress (σ) equivalent to that of the locust leg muscle ($8 \times 10^5 \text{ N m}^{-2}$)^{5,7}, and with the assumption of an elastic extension of the sarcomere (n) equal to 30 nm⁵, muscle density (ρ_m) of 1060 kg m^{-3} ⁵, and muscle fibre mass (m), using the following equation⁵:

$$U/m = \sigma n / \lambda \rho_m \quad (6)$$

The strain energy stored per unit mass of the extensor muscle (U/m) is thus approximately 2.9 J kg^{-1} , yielding 0.002 J for the entire extensor muscle mass (0.8 g). Based on this value of maximal strain energy in the muscle, we estimated the strain energy stored in the apodeme (U_t) as follows ⁵:

$$U_t/U = (\lambda/2n)(\Delta l_t/l) \quad (7)$$

We assumed a 3% change in apodeme length (Δl_t) ⁵ equal to 0.7 mm , and an actual muscle fascicle length (l) equal to 4.9 mm . The strain energy stored in the apodeme is thus approximately 0.045 J .

Based on the power calculations above, and applying values from a typical strike, the work output before impact with a snail equals 0.31 J . Thus, even before any energy has been expended on crushing the snail, the combined estimated strain energy stored in the muscle and apodeme provide a maximum of only 15% of the necessary energy to yield the observed movements, strongly suggesting the need for an additional spring. The above calculations are only approximations of the strike energetics, however we have used values that should over-estimate the strain energy storage in the muscle and apodeme.

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