Supplementary Data 2.—In order to calculate the vertical component of drag, D_v, a modified version of Eq. 9 was developed that accounts for the starting position of the arm relative to vertical, α, and the angle through which the arm rotates, θ, the latter of which affects the angular velocity of the arm, ω. The instantaneous vertical component of thrust is found via trigonometry as:

$$D_{Vinst} = D_{Tinst}\sin(\alpha) \tag{10}$$

To get total vertical thrust, Eq. 10 is integrated with respect to time during the translation of the arm from the start of the power stroke to its completion, from t=0 to t=t:

$$D_V = \int_0^t D_T \sin(\alpha) dt \tag{11}$$

$$D_V = D_T \int \sin(\omega t) \tag{12}$$

$$D_V = D_T\left(-\frac{\cos(\alpha)}{\omega} + \frac{\cos(\alpha+\theta)}{\omega}\right) \tag{13}$$

Eq. 13 is slightly rewritten in the text as Eq. 4, and is the model's analytical solution.