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INSIDE JEB

Zebra finches turn up wing power by flapping further

An incoming zebra finch. Photo credit: Jim Bendon from Karratha, Australia/CC BY-SA.

Where ever you spend summer, insects are likely to be on the backing track. Flapping their wings at blisteringly fast speeds, some of the buzzing creatures have evolved a specialised form of muscle that generates high forces while contracting at superfast rates, to overcome the convention that fast-contracting muscles don't generate high forces. How tiny birds that dart around at speeds rivalling those of insects pull off the feat was more of a mystery. 'Michael Dickinson suggested that it could be informative to address the high wingbeat frequency problem in birds when I was a postdoc', says Doug Altshuler, from the University of British Columbia (UBC), Canada, adding that Dickinson suggested he try to apply a technique – the work-loop method – popularised by Robert (Bob) Josephson to answer the question. However, despite several early attempts, including collaborations with Josephson and Ken Welch, Altshuler made little progress measuring the forces generated by zebra finch flight muscles until Joseph Bahlman joined him at UBC.

'Joe proposed that we let go of re-engineering Bob's work-loop rig and instead go with a commercial supplier', says Altshuler, recalling how Bahlman suggested using an ergometer built by Aurora Scientific with the right range of strain and force sensing. In addition, Bahlman designed a custom-built support, tailored to each zebra finch, to hold the bird gently in place as the pectoral muscle relaxed and contracted. 'Joe has a strong background in engineering, which proved essential for the measurements to work', says Altshuler.

After more than a decade of chipping away at the problem, Altshuler, with Bahlman and Vikram Baliga, was ready to check whether the new rig would accurately measure the force produced by the bird's flight-powering pectoral muscle. And he was impressed when Bahlman calculated a peak muscle stress of 101 kN m^{-2}, similar to the values calculated by other scientists. It also became apparent during preliminary experiments that flapping the wings through a wider arc might help the birds to generate more power. Bahlman then began the painstaking task of measuring how stretching the muscle (to simulate the wider wing beat) affected the force produced, while also adjusting when simulated nerve signals triggered a muscle contraction, in addition to altering the length of the nerve signal and the frequency of the simulated wing beat. Shortly after completing the experiments, Bahlman joined California State University, Sacramento faculty, so Baliga stepped in to complete the herculean task of calculating the amount of work done by the muscle and the power produced over the course of each of the experimental contractions.

After months of detailed calculation, it was clear that the muscle produced most power by stretching farther to increase the range of the bird's wing sweep. More surprisingly, increasing the frequency of the wing beat was counter-productive, causing the bird to lose power. 'If zebra finches need to produce more power to manoeuvre, fly faster or escape a predator, it will be more efficient for them to do this by increasing wing stroke amplitude', explains Altshuler.

Sadly, however, Josephson did not live to see the results of Bahlman's innovations. 'We invited Bob for a seminar in around 2014 to help get Joe started and we had a great visit. Sadly, Bob got sick shortly after and passed away before I was able to see him again', Altshuler reminisces, adding, 'All the methodology and data collection occurred after we stopped working together'. But he still wants to recognise Josephson's pivotal contribution to the study's inception and preliminary development, dedicating the paper to his memory.

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