INSIDE JEB

Scampering marmosets fine-tune movements to bendy boughs

A marmoset on Itamaracá island, Pernambuco, Brazil: Photo credit: Cynthia Thompson.

The spectacle of a tightrope walker apparently suspended in mid-air on a thread-like cable has mesmerised crowds for generations, from Charles Blondin's first crossing of the Niagara Gorge in 1859 to Philippe Petit's 1974 death-defying 'coup' traversing a 61 m-long cable, 400 m above the ground between the twin towers of the World Trade Center. Yet awe-inspiring aerial displays are routine for many tree-dwelling species. 'The ease with which primates can walk and run over narrow and compliant branches has long fascinated both scientists and the public', says Jesse Young from Northeast Ohio Medical University, USA, who has spent the last 5 years investigating how tree-dwelling species negotiate their complex surroundings. 'We've amassed a large dataset on how primates adapt their walking and running patterns to cope with variation in perch diameter', he says. Yet, little was known about how primates tackle the challenge of bounding along a springy tree limb. Intrigued by this knowledge gap, Young and Brad Chadwell decided to investigate how marmosets take pliable surfaces in their stride.

'Figuring out how to motivate the animals was the most difficult part', says Young, recalling how he and Chadwell encouraged the marmosets to scamper atop tubes ranging in diameter from 1.25 to 5 cm with puffs of air aimed at the tail and tempting fruity yoghurts – 'Which they would get all over their faces', he chuckles. 'They were also a little freaked out the first time we transitioned them from the stable to the compliant substrates', adds Young, describing how he and Chadwell eventually hit on the idea of supporting the tubes with super-cushioning polyurethane foam to simulate the movement of a bouncing bough as a marmoset scurried along. Then, having fine-tuned the marmosets' running track, the duo filmed the monkeys in 3D as they scampered from one end to the other.

Analysing the bucking motion of the tube and the details of the marmosets' strides, Bethany Stricklen, Young and Chadwell realised that the animals' hindfeet remained in contact with the pipe for longer when it flexed: 'Increasing substrate contact time may improve stability on narrow and compliant supports by giving the monkeys more time to react to perturbations and use substrate reaction forces to redirect the centre of mass appropriately', says Young. The team also noticed that the marmosets were able minimise the deflection of the springy trackway by lowering their bodies closer to the tubes and moving more slowly: 'Even a moderate level of compliance exerts a significant influence on locomotor mechanics', says Young. And when the team analysed how the marmosets adapted to the different diameter runways, it was evident that they stopped bounding and switched to a slower gait that allowed them to always keep at least one foot in contact with the narrower tubes.

Referring to the animal's natural tree-top homes, Young says, 'Adjustments to gait mechanics, like those documented here, are undoubtedly one of the many "solutions" arboreal quadrupeds use to achieve locomotor stability in precarious locomotor environments'. He also adds, 'These results clearly show that compliance is an important determinant of locomotor performance that shouldn't be ignored in future studies of arboreal animals'. And Young is eager to learn more about the movements of other primates that have better-developed grasps than those of the marmosets, while hoping eventually to transfer this study into the forest to learn how the natural variation in stiffness from sturdy boughs to bendy twigs affects the animals' movements in their tree-top homes.

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Young, J. W., Stricklen, B. M. and Chadwell, B. A. (2016). Effects of support diameter and compliance on common marmoset (*Callithrix jacchus*) gait kinematics. *J. Exp. Biol.* **219**, 2659-2672.

Kathryn Knight

Thirsty zebra finches burn fat for hydration

Zebra finches on a perch. Photo credit: Joanna Rutkowska.

Except in the case of a few exceptionally hardy species, a regular water supply is essential for the survival of most creatures. 'In birds, water shortage impairs reproductive investment and may set limits to potential habitat, flight range or flight altitude during migration', say Joanna Rutkowska, Edyta Sadowska, Mariusz Cichoń and Ulf Bauchinger from Jagiellonian University, Poland. However, some animals under extreme exertion can supplement their water supply with water generated as they consume their own tissues: proteins can release 0.82 g of water for every gram of tissue consumed, while fats liberate 1.1 g of water. However, it was less clear how birds that are simply going about their day-to-day business manage water production. Bauchinger explains that despite the greater potential for fat to release metabolic water, protein had been considered the main source of water as protein molecules are always associated with bound water that would be released as the proteins were broken down. Curious to find out more about how birds

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generate metabolic water, Rutkowska and colleagues put zebra finches on a diet.

Allocating the birds to one of three groups (unlimited access to food and water, access to water alone and access to neither) for 24 h, the team then measured the animals' metabolic rates before analysing the composition of their bodies to find out how the birds had managed their metabolism while fasting. Impressively, despite having deprived a third of the birds of water for a day, all of the birds were equally well hydrated. However, their body composition varied dramatically, with the birds that had no access to food or water losing almost 0.4 g fat, relative to the fasting birds that could still drink, which lost only 0.047 g fat. And when the team converted the fat loss into water generated, the water-deprived birds were able to generate an impressive 0.444 g of water by simply burning their own fat.

Considering how much protein from body tissues the birds would have to consume to match the water produced by fat, the team points out that the starving water-deprived birds would have to metabolise a potentially life-threatening amount of protein, equivalent to three times the mass of their own hearts or one-third of their flight muscle mass. 'Although protein catabolism would be probably spread over different organs, this exemplifies that catabolism of such an amount of protein would severely constrain tissue function, not only during fasting but also when food intake is re-established', the team says.

So, water availability is essential for fasting birds to maintain their fat stores and the team says, 'We revise currently established views [that protein catabolism is the main source of metabolic water] and propose fat serves as the primary source for metabolic water production'.

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Rutkowska, J., Sadowska, E. T., Cichoń M. and Bauchinger, U. (2016). Increased fat catabolism sustains water balance during fasting in zebra finches. *J. Exp. Biol.* **219**, 2623-2628.

Kathryn Knight

Exertion alters egg antioxidant levels

Zebra finches performing social grooming. Photo credit: Ajman Adil.

Some mums have a long way to go before they can lay eggs, from the Arctic terns that voyage north from Antarctica, to the enigmatic swallows that migrate to Europe from Africa each year. But what impact do these extreme exertions and the diets that these birds consume have on the quality of the eggs that they lay upon their arrival? 'Physiological challenges during one part of the annual cycle can carry over and affect performance at a subsequent phase', say Megan Skrip and colleagues from the University of Rhode Island, USA. However, investigating the direct impact of these factors in migrating species would be an almost impossible task, so Skrip and Scott McWilliams turned to a more sedentary and well-understood species – the zebra finch – to discover how diet and migration affect how females allocate nutrients to their eggs.

Although zebra finches are not migratory, Skrip explains that they simulated the effects of a large-scale migration by encouraging the birds to take regular exercise flights back and forth between perches over a period of 6 weeks in the lab: 'Repeated takeoffs and short flights require three times the energy of sustained flapping flight', she says. And by spiking the drinking water of some of the birds with lutein, catechin and anthocyanin antioxidants, the team was able to test whether the antioxidants provide any protection from the effects of endurance flight and whether the benefits were also passed on to the eggs.

Monitoring the antioxidant levels in the birds' blood – before and after their simulated migration and after they produced a clutch of eggs – the team could clearly see that the birds suffered oxidative damage as a result of their exertions. Even the birds that were supplied with antioxidants in their drinking water were not fully protected from the effects of the exercise; when the team searched for an increase in antioxidant levels in the blood of these birds, they were surprised to see that the protective antioxidant levels did not increase. However, the team suspects that if the birds had consumed the antioxidants as part of their diet, instead of in their water, they may have experienced some benefits: 'It's possible that the absence of a natural food matrix resulted in lower absorption of dietary antioxidants', they say.

Turning their attention to the clutches of eggs laid by the birds after 6 weeks of flight training, they were intrigued to see that the eggs had lower levels of the antioxidant carotenoid lutein, suggesting that the mothers had expended the antioxidants for their own protection during flight training, although the levels of vitamin E passed on to the eggs were unaffected by the zebra finch's exertions. Furthermore, the eggs of birds that had received dietary supplements had lower levels of lipid-soluble antioxidants (lutein) than those of birds that had received no supplements, contrary to expectations. The team also found that the eggs increased in size as the birds expanded the clutch, which they suggest may compensate for the reduction in antioxidants in the eggs.

'For the first time, our experiment demonstrated that antioxidant supplementation and endurance flight together produce effects on allocation of lipid-soluble antioxidants to eggs by female zebra finches', say Skrip and colleagues, who suspect that the impact of the parents' exertions on the quality of their eggs will extend to the next generation.

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Skrip, M. M., Seeram, N. P., Yuan, T., Ma, H. and McWilliams, S. R. (2016). Dietary antioxidants and flight exercise in female birds affect allocation of nutrients to eggs: how carry-over effects work. *J. Exp. Biol.* **219**, 2716-2725.

Kathryn Knight
kathryn.knight@biologists.com