Feeding behavior in monkeys and humans have ancient, shared roots

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This is a curious "teenage" (sub-adult) male spider monkey. Credit: Annika Felton

Behavioural ecologists working in Bolivia have found that wild spider monkeys control their diets in a similar way to humans, contrary to what has been thought up to now. Rather than trying to maximize their daily energy intake, the monkeys tightly regulate their daily protein intake, so that it stays at the same level regardless of seasonal variation in the availability of different foods.

Tight regulation of daily protein intake is known to play a role in the development of obesity in humans, and the findings from this research suggest that the evolutionary origins of these eating patterns in humans may be far older than suspected. Until now it was thought humans' eating patterns originated in the Palaeolithic era (between 2.4 million and

10,000 years ago).

The research, published online today (Wednesday 20 May) in the journal *Behavioral Ecology*, also provides valuable information about which trees are important for the monkeys' diet, which is relevant to conservation; in addition, it may help to improve the care of captive primates, which can be prone to obesity and related health problems due to their diet.

Dr Annika Felton, a Departmental Visitor at the Fenner School of Environment and Society, The Australian National University, Canberra, Australia, spent a year in the Bolivian rainforest (in Departmento Santa Cruz) familiarising the Peruvian spider monkeys (*Ateles chamek*) to her presence and then observing their feeding habits.

She followed 15 individual monkeys (7 adult males, 8 adult females), conducting continuous observations of the same animal from dawn to dusk, and following each of the monkeys for at least one whole day a month. During observations she recorded everything they did and ate and for how long. Where possible, she counted every fruit and leaf they ate, and collected samples of what they had eaten from the actual trees the monkeys had chosen. The samples were then dried and sent to the laboratory in Australia where they were analysed for their nutritional content. It is unusual for a study of feeding habits in wild primates to be conducted in this detailed way. It enabled Dr Felton and her colleagues to calculate how much an individual monkey had consumed and the nutrients involved; usually, other field studies are only able to calculate averages for a group of animals.

Dr Felton said: "We found that the pattern of nutrient intake by wild spider monkeys, which are primarily fruit eaters, was almost identical to humans, which are omnivores. What spider monkeys and humans have in common is that they tightly regulate their daily protein intake, i.e. they

appear to aim for a target amount of protein each day, regardless of whether they only ate ripe fruit or mixed in other vegetable matter as well. Finding this result in spider monkeys was unexpected because, previously, ripe fruit specialists were thought to be 'energy maximisers'. In other words, they would aim to maximise their daily energy intake. Our findings show this is not the case.

"The consequence of tight protein regulation is the same for monkeys and humans: if the diet is poor in protein but rich in carbohydrates and fats (energy dense food) individuals will end up ingesting a great deal of energy in order to obtain their protein target, which can lead to weight gain. This 'protein leverage effect' is thought to play a significant role in the human obesity problem found in modern western societies. Our results suggest that an adjustment of the nutritional balance of diets as a means to manage human obesity might similarly be an option for mitigating obesity in captive primates.

"Our findings are also interesting from an evolutionary point of view. Similarity in the regulatory pattern of protein intake between distantly related species, such as humans and spider monkeys, possessing very different dietary habits, may indicate that the evolutionary origins of such regulatory patterns are quite old, potentially far older than the Palaeolithic era. If we are not dealing with convergent evolution here - in other words that spider monkeys and humans have evolved this trait independently - then this trait may have been shared by our common ancestor. Spider monkeys are New World primates that split from the Old World primates about 40 million years ago.

"Finally, our research shows that nutritionally-balanced food sources that are used extensively by a wild population may need special attention in terms of conservation planning, perhaps by regulating logging and selecting certain tree species for re-planting. The majority of the monkeys' nourishment was sourced from a species of fig tree, Ficus

boliviana, that is currently being harvested for timber in Bolivia."

Dr Felton and her colleagues found that the monkeys ate a wide variety of fruit and vegetables - 105 different plants belonging to 63 species during the 12 months of observation. Figs were particularly popular. The monkeys rarely ate insects, which are rich in protein.

The spider monkeys did not specifically select either the most energy-rich or the most protein-rich foods that were available, and the daily amount of food they ate varied quite widely, averaging about 1 kg a day, but sometimes as much as 2.4 kg a day. However, they maintained their daily protein intake around 0.2 MJ (11 grams), whereas their intake of carbohydrates and fats varied between 0.7-6.2 MJ. The availability of sweet, ripe fruit was significantly related to the variation in their daily energy intake - the more there was, the more they ate.

"To maintain a stable intake of protein, spider monkeys consumed large amounts of carbohydrates and fats when protein content in the food was low, for instance when their diet consisted entirely of ripe fruit, and consumed far fewer carbohydrates and fats when feeding on items rich in protein," said Dr Felton.

She concluded: "What is perhaps most fascinating about our paper is not the answers we provide, but the questions that our findings raise. For example, why do these frugivores have the same pattern of nutritional intake as human omnivores? Is this due to convergent evolution or is it a remaining trait from a common ancestor?

"I am also pleased that our findings can be applied to the management of captive primates (where obesity is a problem), and possibly the management of spider monkey forest habitat.

"Also, importantly, we have shown that the combination of intensive

data collection and the application of an innovative analytical framework can dramatically change our perceptions of the nutritional ecology of a species."

More information: Protein content of diets dictates the daily energy intake of a free-ranging primate. *Behavioural Ecology*. Published online under advance access. doi:10.1093/beheco/arp021

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