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Determining Variation in Flight Speed and Pattern of Cliff Swallow Using Video Frame Analysis

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ABSTRACT
Ability to fly faster varies from one species of birds to the other. Take off from their nest, settling on the nest or migratory speed of flight is different from one bird to the other, so is also to Cliff Swallows. Many workers have tried different ways to analyze the flight speed of birds using principles of mechanics and physics. Here we have analyzed take off and settling in speeds of Indian Cliff Swallows by applying Video frame analysis technique with fixed focal length.
KEYWORDS: Take off, Landing, Hovering, Flight speed analysis, Video frame analysis

I. INTRODUCTION

Ability to fly is the key adaptation that has made the birds so successful. Migratory flights without any break over thousands of kilometers are unique and surpass the performance of any man made vehicle of a similar size (A Hedenstrom, 2002).Study of bird flight has now become an interesting aspect by involving different types of birds in the world. Each type of the bird has their own flight characteristics applicable to their nature of life. The comparative account of such studies can be used to optimize the development of flying machine.

The birds flying machinery includes wings, feathers, wing bones, flight muscles and to the least extent its legs. The birds' wing is similar to that of human arms in many aspects (Tricker&Tricker 1967). The portion of wing between the shoulder joint and the elbow joint is not aerodynamically significant for most birds & it is neglected in calculations. The cross section of the bird's wing is quite similar to the airfoil section of the aircraft (Houghton and Carruthers 1982). By adapting an aerodynamic approach barrowed from engineering and modified to apply to animals has made it possible for biologists to address fundamental questions about the flight in birds. Understanding the role of tail length and shape in flight and understanding the flapping flight aerodynamics is still in its infancy (Simulation of Flapping Flight: Shreyas&Sreenivas K R, 2005; Lift generation mechanism in Flapping Flight: Shreyas J V &Sreenivas, 2006& 2009; Hovering jet creation from Flapping: Shinde S Y &Arakeri J H, 2011). Though the theory of aerodynamics is instantly and widely applied to analyze the birds' flight has not given a satisfactory means of flight analysis as revealed in the above perused works.

With application of computer knowledge several aspects could be made easy. With this back ground knowledge it is now undertaken to analyze different flight speeds in our model bird cliff swallow through computer image analysis which would solve many of the problems involved in analyzing the bird flight speed.

The new approach what we are proposing is the determination of speed and flying pattern of bird flight using Computer Vision's Video/Image Processing; this approach has given the way to analyze the flight speed at different stages without taking the physical or biological factors of bird and environment into consideration.

II. MATERIALS AND METHODS

The material used in the study and calculation of the speed of the Cliff Swallow is Sony Cyber shot which technical works at 25FPS (Frames per Second) for the purpose of a recorded video of the bird at different stages at the breeding site, in and around the Cliff and its Nest and the Computer aided Tools Used for the design and analysis are Visual C++ 2010 Express as an IDE and OpenCV2.2 as the API's.

Microsoft Visual C++ 2010 Express is a set of freeware integrated development environments (IDE) developed by Microsoft that are lightweight versions of the Microsoft Visual Studio product line. The idea of Express editions is to provide streamlined, easy-to-use and easy-to-learn IDEs for users other than professional software developers, such as hobbyists and students. OpenCV product is used for the video processing, the video which has been recorded through Sony Cyber Shot camera with 25fps. Using the functionality of Video/Image Processing through this tool the input video is processed to capture each frame and converted to be as individual JEPG images and using the Matrix Math function for the pixel counting or distance calculation of the object (Cliff Swallow in the image) from nth frame to $(n+1)^{th}$ frame.

III. OBSERVATION

While studying about the physical behavior of Cliff Swallows during nesting and breeding the uniqueness in the Take-off mechanisms and the landing pattern on and off the nest was what without surprise motivated us to dedicate a study on the Pattern adopted by Cliff Swallows for Take-Off, Landing and Hovering. Specifically and technically all these flying and flight controlling features are used and adopted by Swallows for the purpose of Identifying and landing on its nest which is one among approximately 1000 nests in a colony, a colony which exits as a cluster of nests.

The observations made in the physical behavior have brought few interesting facts about these Cliff Swallows which are projected in this paper.

The Cliff Swallows have a unique mechanism during the take-off from their nest, i.e. they shoot for flight in the air such a way that its speed develops from Zero to Maximum in 0.32fraction of second. The Mechanism used by these birds is an excellent way of using the gravity, where most of the birds lack this technique. The technique of using the gravity by making the body to fall towards downward pull of gravity and converting the downward movement or speed for the flight action as shown the Fig-01.

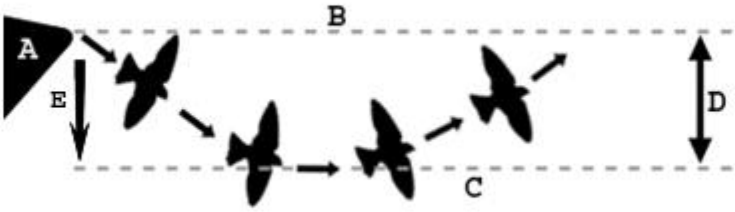

Fig-01: Take-Off pattern of Cliff Swallows (A – Nest, B – Horizontal level axis at nest, C – Approximate Downfall level axis before takeoff, D – Approximate downfall length and E – Gravity Pull).

The mechanism practiced by Cliff Swallows during landing is observed to be Horizontal Curved landing at the nest which follows immediately with Hovering. This Horizontal Curved pattern practiced by these birds is to decrease the speed from maximum to zero for safe and perfect landing at the target as shown in the Fig-02; here the target is the nest which it identifies its own nest during Hovering.

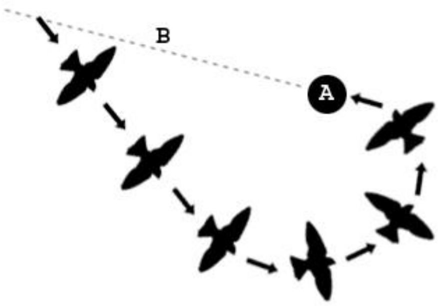

Fig-02: Landing pattern of Cliff Swallows (A – Target (Nest), B – Straight direction to reach target).

The pattern shown in Fig-02 is used by the Cliff Swallows with a horizontal bent curve for the landing at the nest, this type of landing is observed when the birds knows the target at flight. Whereas in some cases finding its nest (target) in the group of nearly 1000 nests is difficult at run to find its target at the travelling speed, hence as to encounter this finding with target initially it hovers for 0.36 fraction of a second to identify the target. And once the target is found for landing it may not require to follow the Horizontal Curved Pattern landing as it would have already decreased the speed for hovering or while hovering.

The physical components of the bird - wing size, wing width, body length or weights have nothing to do with the speed measurement using computer image analysis. The speed of the Cliff Swallows is calculated at different stages of take-off from the nest, landing at the nest and speed maintained during/for hovering.

Digital Images are the composition of pixels as the basic component and hence the number of pixels depends upon the screen/image resolution and size, hence image in the digital world varies in its size which represents virtual real-world image with identical structure but not its size. Being aware of this fact we need to map the digital world entity (Pixel) to the real world entity (Centimeters) which is used to calculate the unit of distance respectively by mapping each Centimeters to number of pixels. The mapping is done using the same capture tool which was used to capture the flight of Cliff Swallow as well to project at some real-world object as shown Fig-03.

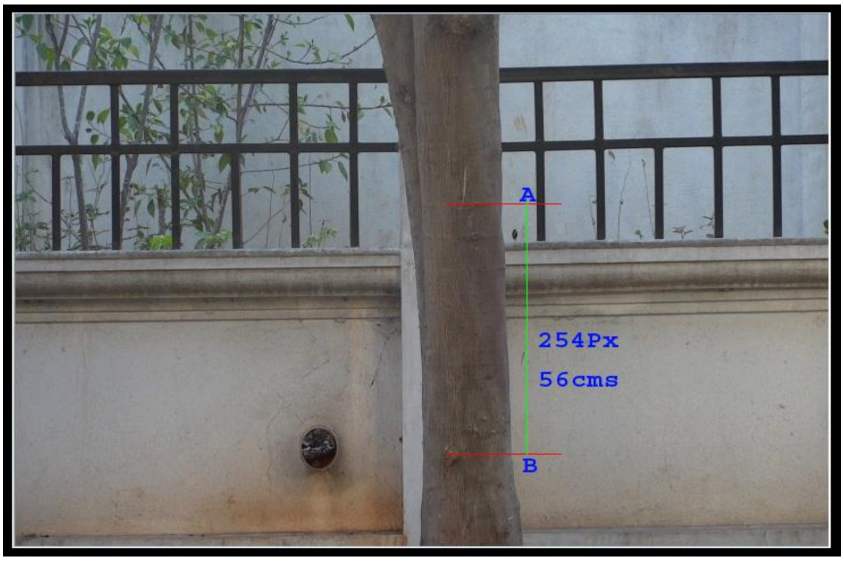

Fig-03: Mapping Digital pixel to the real world length.

Then the length of the target object in real-world was measured using Measurement tape which read to be 56cms from point A to point B as shown in Fig-03 and when the digital image which contains the same target object at the focal length, the same focal length with which the bird appears to be captured in the image was processed to know, that it maps to 254pixels from point A to point B of 56cms. Hence by this we know that 254pixel occupies 56cms, therefore to know the distance covered by each pixel we use the cross product formula.

254pixels = 56cms

1pixel = Xcms

After cross product we have,

X = 56cms / 254pixels

X = 0.221cms

These processing and calculation shows that each pixel in digital world is mapped as 0.221cms in real-world. With this analyzed information we calculate the speed of Cliff Swallow at different stages of flight.

Speed Calculating Mechanism using Images:

A recorded video of bird flight is fed as the input to the video processing tool through which we captured each frame and converted it to be images. Later these images were processed to know the position of the object / Cliff Swallow in the image using arrows or the bounding boxes as shown in the Fig-04,-05,-06 and -07.Byconsidering any two consecutive frames/images from the video and calculate the distance (number of pixels) moved by the bird from one frame to another frame. To calculate speed using the formula of speed (Speed = Distance / Time) we need distance (number of pixels) and the time (fps – Frames per Second, which 25FPS).

Travelling near Nest: Using the Frames shown in the Fig-04

By processing these frames we observed that the bird takes 5 frames to cross the complete frame which as resolution width of 720pixels, hence720pixels divide by 5 frames gives 144pixels travelled distance by bird in each frame.

144pixels X 25frames = 3600pixles per second

Each pixel is mapped to 0.22cms.

3600pixels X 0.221cms = 795.6cms/sec

Hence, the speed of Cliff Swallow while travelling near the nest is approximately 795.6cms/sec or 17.8Miles/hr or 28.65Kms/hr.

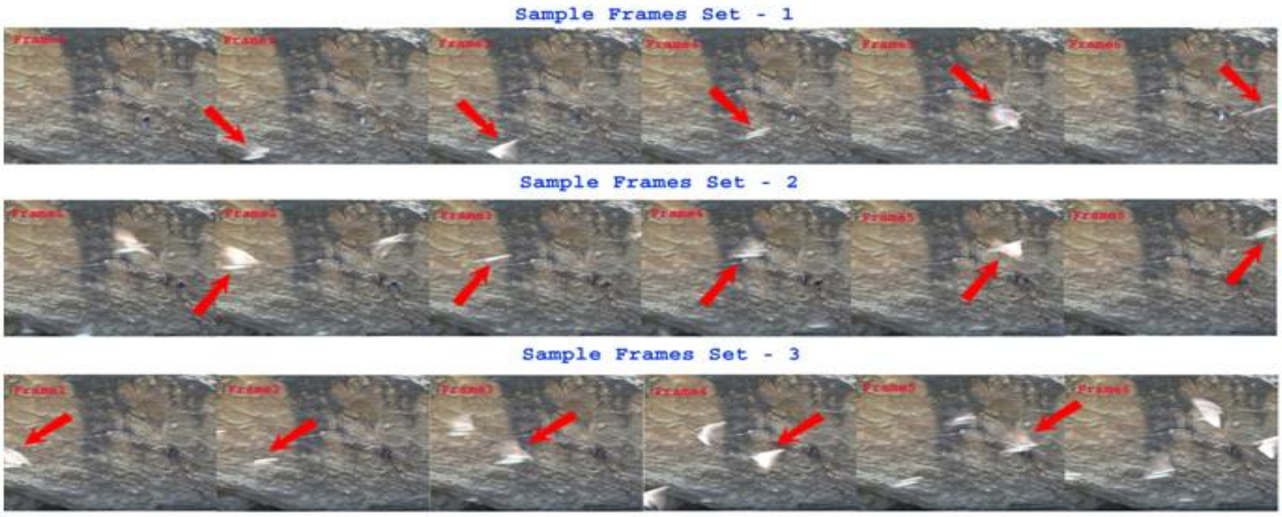

Fig-04: 3 Set of 6 Frames showing birds using red colored arrow to cross the complete frame width.

Speed at Take-Off from Nest:

Using Frames shown in Fig-05 the speed are derived and listed in Table-01.

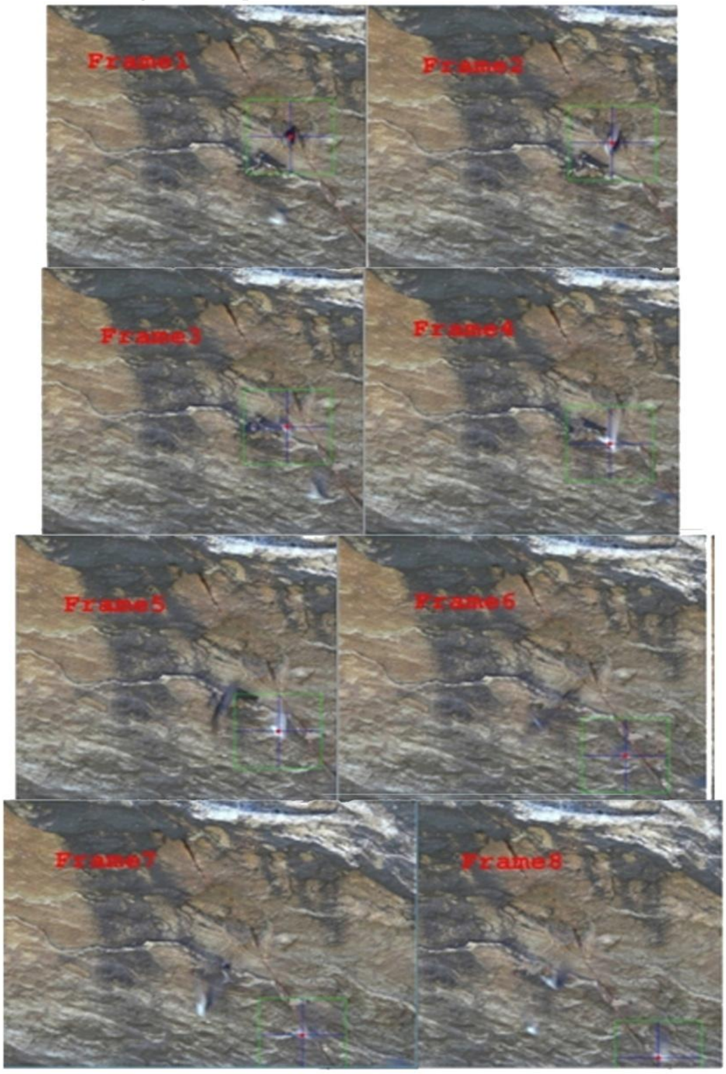

Fig-05: Bird's take-off from Frame1 to Frame8 at slightly varying distance at different stages.

Frame Number (n)	**X – Position in Pixels**	**Y – Position in Pixels**	**Distance in Pixels (n to n+1) frames**	**Speed in Km/hr**
1	350	190	0	0.0
2	348	202	12.17	2.422
3	348	247	45	8.95
4	348	280	33	6.57
5	378	322	51.61	10.27
6	420	370	63.78	12.69
7	448	400	41.04	8.17
8	505	445	74.52	14.83

Table-01: Varying speeds during take-off from nest.

Speed at Landing on Nest:

Using Frames shown in Fig-06 the speed are derived and listed in Table-02.

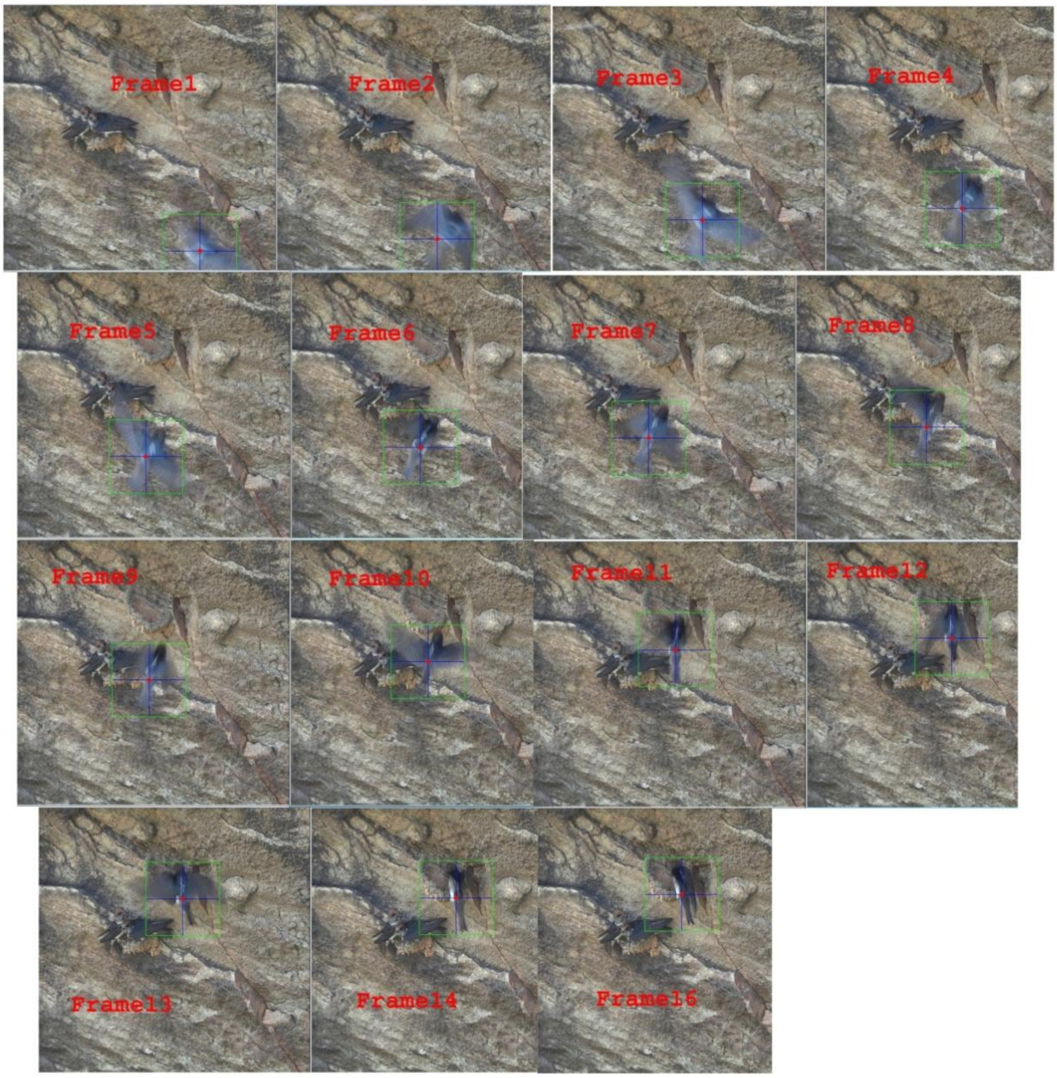

Fig-06: Bird's landing at nest from Frame1 to Frame15 at slightly varying distance at different stages.

Frame Number (n)	**X – Position in Pixels**	**Y – Position in Pixels**	**Distance in Pixels (n to n+1) frames**	**Speed in Km/hr**
1	325	425	0	0
2	250	400	79.06	15.73
3	230	360	44.72	8.9
4	200	335	39.05	7.77
5	185	300	38.08	7.58
6	185	280	20	3.98
7	182	258	22.2	4.42
8	189	235	24.04	4.78
9	194	210	25.5	5.07
10	203	172	39.05	7.77
11	214	145	29.15	5.80
12	218	120	25.32	5.04
13	220	110	10.2	2.03
14	218	107	3.61	0.72
15	217	100	0	0

Table-02: Varying speeds during landing at nest.

Speed at Hovering near Nest:

Using Frames shown in Fig-07 the speed are derived and listed in Table-03.

Fig-07: Bird's hovering near nest from Frame1 to Frame14 at slightly small varying distance at different stages.

Frame Number (n)	X – Position in Pixels	Y – Position in Pixels	Distance in Pixels (n to n+1) frames	Speed in Km/hr
1	-65	357	0	0
2	-23	335	47.41	9.43
3	12	300	49.5	9.85
4	28	295	16.76	3.34
5	50	260	41.34	8.23
6	48	255	5.39	1.07
7	50	250	5.39	1.07
8	50	250	0	0
9	37	244	14.32	2.85
10	28	247	9.49	1.89
11	12	242	16.76	3.34
12	7	235	8.6	1.71
13	5	233	2.83	0.56
14	33	270	46.4	9.23

Table-03: Small Varying speeds during hovering near nest.

IV. DISCUSSION AND CONCLUSION

Our study on Indian cliff swallows has revealed that when these birds take off from their nest they shoot down in the air to develop speed from zero to maximum in0.32fraction of second as shown in Fig-05, Table-01 and such mechanism of flight speed is lacking in many other birds. While these birds have to reduce their speed to land on nest these follow horizontal curved flight mixed with flap bound & flap glide that reduces the flight speed to zero gradually 0.56fraction of second as it lands on the nest as shown in Fig-06, Table-02. The capability of such speed control may be due to wing shape of this bird.

In earlier works of (Kimberly and Prumthe, 2003), (Douglas and Kenneth, 1998), (Hedenstrom A, 2002), (C.J. Pennycuick. 2001) and (C.J. Pennycuick, A Hedenstrom, and M Rosen, 2000)onspeed of flight analysis in birds have involved many formulations, calculations, physical parameters as recorded parameters and substitutions. Even without such a huge involvement of mathematics and physics, the speed on birds could be recorded as we have shown in our case. This is an added advantage in Aviation or Navigation of flying birds or any other aspects to calculate the speed. Here the recorded videography of flight is converted to images using software. Hence this procedure is more advantageous and has more applications. The mechanisms of takeoff, landing and hovering could be utilized to designs in bionics. This principle could be utilized to move any bionic designed gadget in to an unreachable spot by human beings.

REFERENCES

[1] Tricker RAR & Tricker BJK, 1967, The Science of Movement, Mills & Boon, London.
[2] Houghton E L, Carruthers N B, 1982, Aerodynamics for Engineering students, Arnolds, London.
[3] Shreyas J V & Sreenivasa K R, 2005, Experiments and Simulation of Flapping Flight proceedings of SAROD, Tata McGraw Hill.
[4] Shreyas J V., and Sreenivas K R, 2006, Identification of new lift generation mechanism in flapping flight, Proceedings of the Eleventh Asian Congress of Fluid Mechanics, Kuala Lumpur, Malaysia.
[5] Shreyas J V, Devaranjan S, and Sreenivas K R, 2009, A parametric study of new-lift generating mechanism in flapping flight: Experiments and Simulations, Proceedingsof Symposium on Applied Aerodynamics and Design of Aerospace Vehicles (SAROD), Bengaluru, India.
[6] Shinde S Y & Arakeri J H, 2011, Hovering & Jet Creation from a Flapping Two Dimensional Flexible foil.
[7] Kimberly and Prumthe, 2003, High-speed video analysis of wing-snapping in two man akin clades(Pipridae: Aves), The Journal of Experimental Biology 206, 3693-3706, The Company of Biologists Ltd, doi:10.1242/jeb.00598.
[8] Douglas and Kenneth, 1998, Kinematic, aerodynamic and anatomical mechanisms in the slow, Maneuvering flight of pigeons, The Journal of Experimental Biology 201, 655–672, Printed in Great Britain, The Company of Biologists Limited, JEB1221.
[9] A Hedenstrom, 2002, Aerodynamics, evolution and ecology of avian flight, Trends in Ecology & Evolution 17:415-422.
[10] C J Pennycuick, 2001, Speeds and wing beat frequencies of migrating birds compared with calculated benchmarks, J .Exp. Biol. 204, 3283-3294.
[11] C J Pennycuick, A Hedenstrom and M Rosen, 2000, Horizontal flight of a swallow (Hirundorustica) observed in a wind tunnel, with a new method for directly measuring mechanical power. J. Exp. Biol. 203(11): 1755 – 1765.