So Why Would a Pigeon Stand on One Leg (or Limp Without Hurting)?

Zdeslav Hrepic, Columbus State University, Columbus, GA

While we still do not have a definitive answer about the reason(s) for which birds stand on one leg,[1] a list of suggestions has been offered both by expert ornithologists and amateur birdwatchers. We offer a perspective grounded in statics and rotational dynamics that has not been suggested in the literature. The discussion has implications for bird study, and it can also be used as a rich context for teaching statics and dynamics topics at levels ranging from conceptual courses to advanced mechanics.

When investigating behavior of flamingos, Anderson and Williams[1] found these birds prefer resting on one leg rather than on two legs—regardless of location. However, the reduction of muscle fatigue while standing on one leg, as a possible explanation for this behavior, has not been so far experimentally supported.[2] Also, flamingos need more time to initiate forward motion after standing on one leg than after standing on two. Anderson and Williams suggest these limitations discount the possibility that unipedal resting may either reduce muscle fatigue or that it could serve to enhance predatory escape.

Anderson and Williams, however, observed that the percentage of birds resting on one leg decreases as the temperature rises. This strongly suggests that unipedal resting aids flamingos in thermoregulation. The thermoregulatory function is further plausible because legs, as non-feathered parts of the body, are an important site of heat exchange for birds.[3] And hiding (one leg) in the plumage reduces the heat loss when sleeping or when standing on ice. Still, other observations suggest that thermoregulation is not the only function of standing on one leg because birds stand on one leg even in a warm environment, and resting birds often just lift one leg without hiding it in the plumage.[2]

Another notable finding is that the percentage of flamingos resting on one leg is significantly higher among birds standing in water than among those on land.[1] Water facilitates the heat loss so this behavior may also have a thermoregulatory function. But it is also possible that this is done either (1) to dry out the skin, (2) to change their silhouette to look more like vegetation and thus fool prey and predators, or (3) in the case of the flamingos, to hide their bright, fluorescent pink feathers.[4]

Based on statics and the author's observations described below with associated photographs, we suggest that in some cases birds (pigeons in this instance) may stand on one leg simply to gain some physical space when needed.

Mechanics of choosing a narrow path

When standing on one leg, birds (and other animals) need to (i.e., are enabled to!) shift their center of mass (c.m.) above the standing leg support.[2,5]

This account started when the author observed a pigeon limping while walking on a narrow wall platform (incidentally, this happened in Puebla, Mexico, during the XIX International Workshop: New Trends in Physics Teaching). A limping pigeon is not an unusual sight in towns where common city pigeons can be seen on every corner. Those places include also the authors' hometown of Split, Croatia. So other than feeling sympathetic for the bird's trouble, I at first be-

Fig. 1. Pigeons on a narrow wall platform, both standing on the leg that is away from the wall ("outer" leg). When walking, these pigeons appeared to be limping as if the leg closer to the wall (the "inner" leg) was hurting both of them.

Fig. 2. A close look shows that the pigeon's "outer" leg, on which he stands, is as close to the platform edge as possible.

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Fig. 3. Another example of a narrow wall platform one-leg-standing strategy. (Image ©Aaleksander, www.Dreamstime.com)

lieved there was not much to think about this situation. That is, until another pigeon attracted attention by limping on the same platform, and for both of them the "bad" leg was the one closer to the wall.

Before we explore possible reasons for this "synchronous" limping, let us address the statics of standing on one leg in this situation. As seen in Figs. 1–2, when they were not walking, both pigeons were standing on one leg—and both of them used the leg that was farther away from the wall.

The photograph in Fig. 3 (found in an online repository) also shows a pigeon on a narrow platform. The bird seems to be doing the same thing as the pigeons described above – leaning away from the wall with one leg support as far from the wall as possible. This pigeon, however, did not fully lift the "inner" leg. As it is not necessary to lift it, to balance on the outer leg, it is enough not to lean (i.e., press down) on the inner one, with or without fully lifting it.

The shift of the pigeon's center of mass (c.m.) when standing on one leg is clearly visible by comparing the two photographs in Fig. 4.

Why is the shift of center of mass advantageous in the sense of space acquisition on a narrow platform? Because the shift in the body position enabled by the one-leg standing permits the pigeon to stand on the narrow platform without being pushed off it by the wall (Fig. 5).

Assuming the left-right body symmetry, the amount of the sideways distance that the bird shifts its c.m. to stand on one leg does not depend on the bird's mass distribution, height, or construction. If we neglect the leg mass (compared to the mass of the rest of the bird's body), the space that can be acquired this way simply depends on the distance between the feet support points.

To illustrate this, we can consider rebalancing of the two symmetric, but otherwise different, beams supported by the same pivots. If we want to shift them both on their right support, we need to move them an equal distance to the right (i.e., half of the distance between the supports) so that the center of mass is positioned above the remaining support.

But shifting the c.m. this way is not enough if the pigeon wants to walk this path. In order to walk, it needs to limp. And limp on the inner leg with respect to the wall. Which brings us to the dynamic advantage of limping.

Why limping without hurting?

When two-legged animals walk, they do that by interchangeably shifting their c.m. above the current supporting leg. One can easily try and observe this in slow motion. The resulting swinging requires side space larger than the side limits of a stationary body. But the wall on one side of a narrow platform does not let the body move as far as needed toward the wall. So while temporarily supported by the "inner" leg, the pigeon's c.m. is further away from the wall than the supporting point. This causes imbalance and "falling over." If a pigeon spends too much time on the inner leg, every moment is bringing it closer to passing the tipping point and falling (flying) down. To prevent the fall, the only solution is to swiftly move the support to the "outer" leg, i.e., the one further away from the wall. Stretching the outer leg further out to prevent the fall (another useful strategy for bipedals) is not a solution here because the platform limits how far out a leg can be supported, and thus the platform edge defines the point of no return when the c.m. passes it.

Fig. 4. Comparison of the center-of-mass position with respect to the support of two- and one-leg-standing pigeons. (Left image, ©Photobunnyuk, www.Dreamstime.com)

All bipedals perform this exact same limping ritual when one of their legs hurts—to reduce the amount of time on it and to avoid putting the c.m. above it for a prolonged time. In the case of wall platform walking, pigeons (and any other two-legged animal in the same situation) would reduce the amount of time on one leg to prevent falling over, regardless of the health condition.

Maybe the pigeons in Puebla, Mexico, that live by the hotel where the invited presenters for international workshops on physics education are accommodated figured this all out by being in good company over the past two decades.

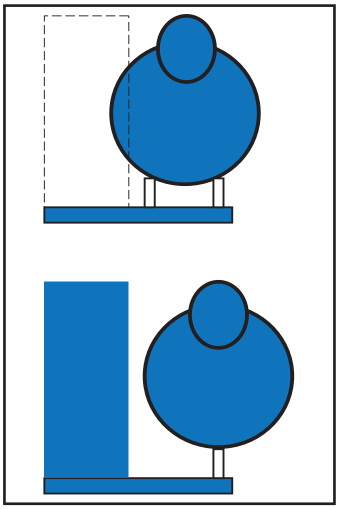

Fig. 5. While standing on the outer leg, the pigeon is stable on a narrow wall platform because the c.m. can still be positioned above the support and without touching the side wall.

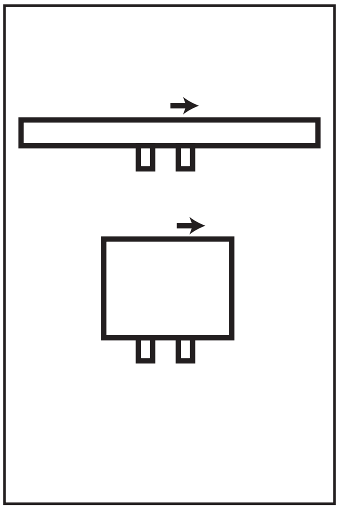

Fig. 6. Rebalancing symmetric beams from two to one support: The shift needed equals half of the distance between the supporting points.

Conclusions and implications for teaching

The one-leg standing and walk on a narrow wall platform presents rich contexts for learning statics and (rotational) dynamics at various levels of physics learning. The context is directly related to the physics of biological systems and as such might be additionally attractive to students of biomedical fields.

The situation is relatively easy to conceptually analyze, it can easily be modeled with beams and similar structures, and it can easily be kinesthetically explored by students' own trials. A slightly more involved task for students would be to determine the minimum width of a wall platform on which a human (or a pigeon) can stand on one leg without falling. Or walk on it without the need for limping.

For advanced students (possibly even those taking advanced mechanics), the question may be how wide the wall platform has to be in order for us to walk on it if we are allowed to take advantage of a limping walk. This problem boils down to determining the time between the step on the inner leg and the time when the c.m. surpasses the outer edge of the platform (the point of no return). This in return depends on the number of assumptions (like how close to the wall we choose to place the "limping" leg, the moment of inertia of the body, etc.). The differential equation describing this situation is of the same format as the equation for a large amplitude pendulum.

$$\frac{d^2\beta}{dt^2} = \frac{mgr}{I}\sin\beta,$$

where r is the arm length between the support point and the c.m., β is a non-zero angle that the arm closes with the vertical, and I is the moment of inertia for the body. The time that the body takes going from the initial to the largest possible angle β defines the longest time for standing on the inner leg if we neglect the inertial effects at that point.

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Zdeslav Hrepic *has a BA in physics and polytechnic teaching from University of Split, Croatia, and MS and PhD degrees in physics education from Kansas State University. He currently is an associate professor of physics at Columbus State University (GA), where he teaches a broad range of introductory physics courses. His primary pedagogical and research interests are technology-enhanced active learning environments.*

Department of Earth and Space Sciences, Columbus State University, Columbus, GA 31907; drz@columbusstate.edu; www.hrepic.com