Researchers uncover aerodynamics of the best attributes of the common jump rope

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(PhysOrg.com) -- One of the cool things about science is, no matter where you are, it's all around you, and sometimes all that's needed is for someone to open their eyes to something that has always just been there. Take jumping rope for example. Jeffrey Aristoff and Howard Stone found themselves wondering one day if the mechanics of the whole operation had ever been studied and worked out. What went on with the rope and what traits made for faster or slower jumping, for example. Last year the two set up a robotic jump rope and filmed the whole process and found that in spite of how things might look to the naked eye, the rope bends out of the plane. Now, a year later, the two have done some more research on the subject and have published their results in *Proceedings of the Royal Society A*.

For those wondering where they might have heard the name Jeff Aristoff before, he was one of the guys working on the research project last year that cracked the subtle dynamics involved in the way cats drink. At the time he was at Princeton, now working for Numerica Corp, he and Stone sought to find out more about what goes on with jumping rope because it seemed like if they did that, then they might uncover secrets about the aerodynamics of other common things going on in the physical world that haven't received much attention, and that could conceivably result in new ways to use them. To that end, they used a real life human model, visiting professor Jiang Li, from China, who is really good at jumping rope.

To find out what was going on as Li jumped, they attached a high speed camera that allowed them to capture the most subtle movements of the rope as Li jumped. In so doing they were able to watch as the part of the rope farthest from her hands (at the bottom of the U) bent backwards slightly due to it being farther from the points where it was being held, which meant of course that it had to travel faster than the rest of the rope. The reason it bent back was because of having to push through air.

Previous studies of rope jumping by others in a vacuum had not seen this. They then put together a rope twirling robot to duplicate what they had observed. Next they filmed the robot doing its thing at high speeds as well, looking in particular at how the rope was impacted by its movement through the air. After that they plugged in everything they had observed into a computer model. Then, by adjusting the size of the rope in the model (its thickness and length) and its weight, they were able to hone their results till they found what they believed to be the traits that led to the optimum jump rope. Thin, lightweight and short.

Now that they believe they've nailed down all that can be had from studying jump ropes, the team believes their research can be applied in other areas, such engineering projects that involve objects moving through the air or that are subjected to air moving past them; particularly those that have thin components such as suspension bridges.

More information: The aerodynamics of jumping rope, Published online before print November 2, 2011, *Proceedings of the Royal Society A*. doi: 10.1098/rspa.2011.0389

Abstract
We consider the influence of aerodynamic forces on the shape of a whirling filament that is held at both ends, i.e. a jump rope. At high Reynolds numbers, the rope curls out of the plane and towards the axis of rotation—a feature we demonstrate via experiment. We derive a pair of coupled nonlinear differential equations that characterize the steady-

state shape of the rope, and the resulting eigenvalue problem is solved numerically. The solution depends on two dimensionless groups: the ratio between the length of the rope and the distance between its ends, and the relative magnitude of the aerodynamic to centrifugal forces. As the latter ratio is progressively increased, the tension in the rope and the out-of-plane deflection increases, until eventually the rope reaches a limiting shape. Finally, we show that the airflow-induced shape change leads to a relative reduction in drag and has implications for successful skipping.