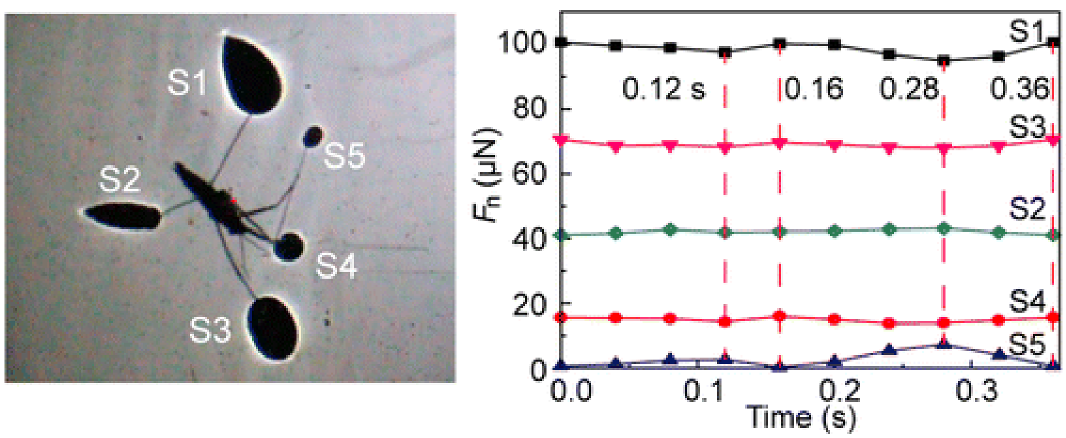
Shadows reveal how insects walk on water

October 19 2016



Credit: American Chemical Society

Water striders' ability to walk and jump on the surfaces of ponds and lakes has long amazed curious observers—and inspired robot designers who want to mimic the bugs' talent. Now, scientists have measured for the first time key parameters that allow them to walk on water—by studying their leg shadows. The findings, reported in the ACS journal *Langmuir*, could contribute to designs for water-skimming robots.

More than 2,000 years ago, Greek scientist Archimedes explained flotation, stating that the upward, floating force on an object in water equals the weight (or downward force) of the water displaced. The principle has informed the building of ships, submarines and other aquatic vehicles. But for tiny water striders, water isn't displaced. It is expelled by the insect's hairy legs. The updated Archimedes principle predicts that the weight of the expelled water should equal the floating force. But confirming this prediction experimentally is a challenge. Because water striders are so light, they are almost impossible to weigh using conventional techniques. So Yu Tian and colleagues used an unconventional method—analyzing the shadows cast by the insects' legs.

The researchers placed a white sheet of paper at the bottom of a lab aquarium housing water striders and installed a light source above the water. The insects' stick-straight legs cast shadows that were rounded, representing the curvature of the water and the expelled water volume from which the floating force and weight can be calculated, the researchers say. Also, from these measurements, the striders' slightest shifts in weight and body angle could be detected for the first time.

More information: Yelong Zheng et al. Elegant Shadow Making Tiny Force Visible for Water-Walking Arthropods and Updated Archimedes' Principle, *Langmuir* (2016). DOI: 10.1021/acs.langmuir.6b02922

Abstract
Forces acted on legs of water-walking arthropods with weights in dynes are of great interest for entomologist, physicists, and engineers. While their floating mechanism has been recognized, the in vivo leg forces stationary have not yet been simultaneously achieved. In this study, their elegant bright-edged leg shadows are used to make the tiny forces visible and measurable based on the updated Archimedes' principle. The force was approximately proportional to the shadow area with a resolution from nanonewton to piconewton/pixel. The sum of leg forces agreed well with the body weight measured with an accurate electronic balance, which verified updated Archimedes' principle at the arthropod level. The slight changes of vertical body weight focus position and the body pitch angle have also been revealed for the first time. The visualization of tiny force by shadow is cost-effective and very sensitive and could be used in

many other applications.

Provided by American Chemical Society