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Water Bouncing Balls: how material stiffness affects water entry

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It is well known that one can skip a stone across the water surface, but less well known that a ball can also be skipped on water. Even though 17th century ship gunners were aware that cannonballs could be skipped on the water surface, they did not know that using elastic spheres rather than rigid ones could greatly improve skipping performance (yet would have made for more peaceful volleys). The water bouncing ball (Waboba®) is an elastic ball used in a game of aquatic keep away in which players pass the ball by skipping it along the water surface. The ball skips easily along the surface creating a sense that breaking the world record for number of skips could easily be achieved (51 rock skips Russell Byers 2007). We investigate the physics of skipping elastic balls to elucidate the mechanisms by which they bounce off of the water. High-speed video reveals that, upon impact with the water, the balls create a cavity and deform significantly due to the extreme elasticity; the flattened spheres resemble skipping stones. With an increased wetted surface area, a large hydrodynamic lift force is generated causing the ball to launch back into the air. Unlike stone skipping, the elasticity of the ball plays an important roll in determining the success of the skip. Through experimentation, we demonstrate that the deformation timescale during impact must be longer than the collision time in order to achieve a successful skip. Further, several material deformation modes can be excited upon free surface impact. The effect of impact velocity and angle on the two governing timescales and material wave modes are also experimentally investigated. Scaling for the deformation and collision times are derived and used to establish criteria for skipping in terms of relevant physical parameters.