Supplementary Data

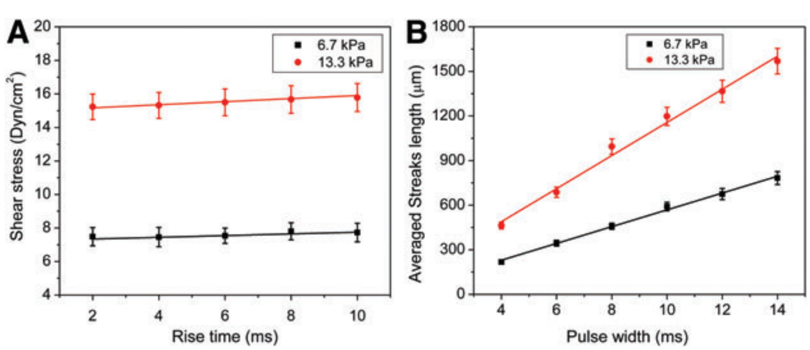
Supplementary Materials

S1: Calibration of rise time of shear pulses

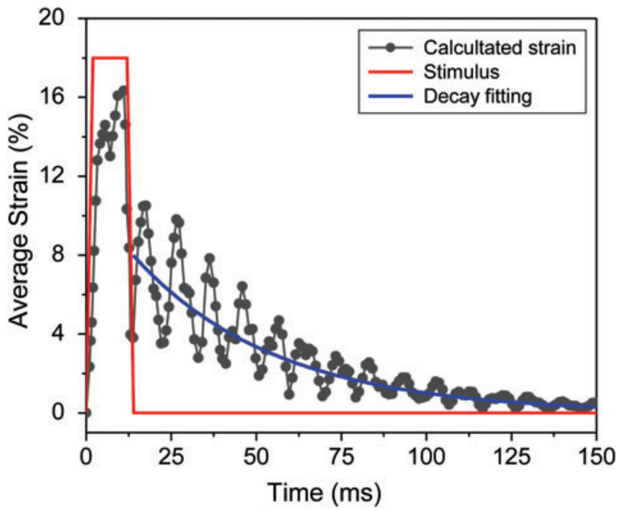
To verify the rise time generated by pressure servo, we measured the linearity of shear stress in the chamber resulting from narrow pressure pulses of different rise times using microspheres. Supplementary Figure 1A shows shear stresses generated by pressure pulses of two amplitudes (6.67 and 13.3 kPa) and 10-ms duration with different rise times above 2 ms. A linear shear stress dependence was obtained under both pressures, showing that 2 ms is sufficient for fluid shear to reach the designed level. The slight increase in shear with rise time is the result of the extra raising time; it is negligible when the pulse width is longer than 10 ms, the narrowest pulse used in this study. Similarly, at the rise time of 2 ms, the average bead traveling distance (streak length) increased linearly with the pulse width (Supplementary Fig. 1B), also supporting that a realiable shear force can be achieved within 2 ms.

S2: Modeling strain distribution in cells subjected to a shear pulse

To evaluate the strain distribution in cells, we constructed a hyperviscoelastic cell model and calculated the time-dependent stress/strain distribution in cells under a shear pulse. A 3D cell model was built within a flow chamber using ANSYS software, and transient fluid-structure interaction was analyzed. The working fluid was considered to be water and the cell to be viscoelastic with the properties described in previously published literature.[34,35] Simulation showed that a shear pulse of 20 dyn/cm^2 and 10-ms width produced a maximum strain of 16%, followed by an oscillatory decay with relaxation time of $\sim$100 ms (Supplementary Fig. 2).



SUPPLEMENTARY FIG. 1. Calibration of rise time of shear pulses in the flow chamber. (**A**) Shear stresses produced by inlet pressures of 6.7 (black) and 13.3 kPa (red) with different rise times. (**B**) Dependence of streak length of the beads on pulse width at inlet pressures of 6.7 (black) and 13.3 kPa (red) and 2-ms rise time, showing that streak length linearly increases with pulses width.



SUPPLEMENTARY FIG. 2. Finite element analysis of strain distribution in a cell under a shear pulse of 20 dyn/cm^2 and 10-ms width and rise time of 2 ms. The cell was assumed hyperviscoelastic and has a star shape with average diameter 20 μm and maximum height 3.5 μm. An exponential decay function was used for the fitting (blue curve).