

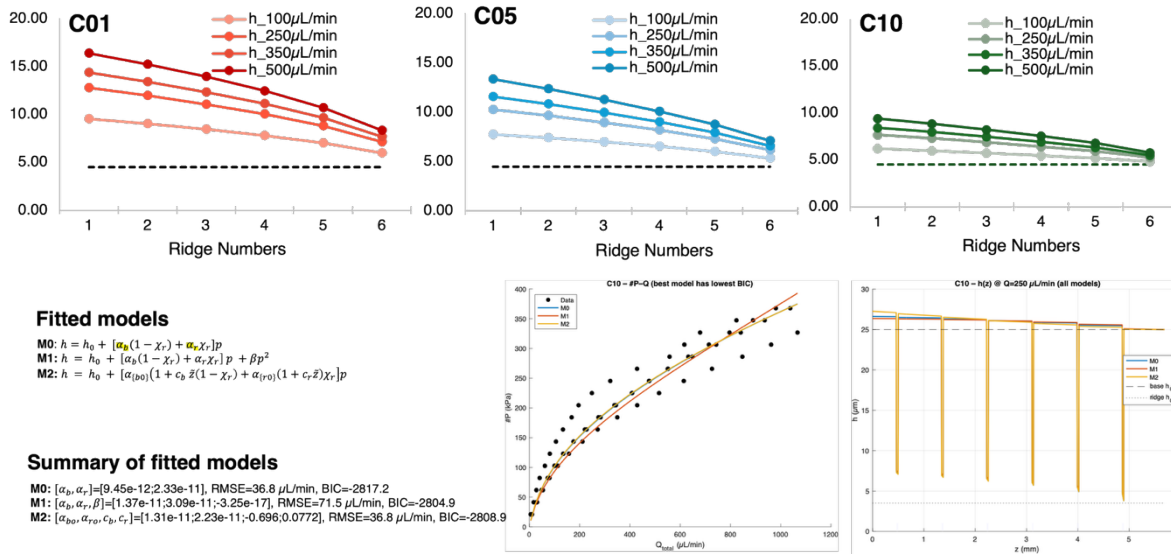
Supplementary Tables

Supplementary Table 1: Reynold's number calculations for design variants at the three tested total flow rates of 100µL/min, 250µL/min and 350µL/min.

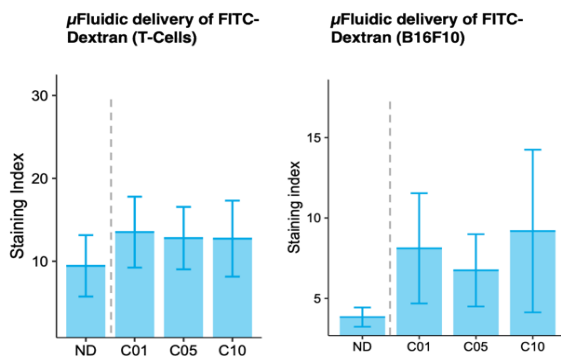
Parameter	Computation method	Units
t_{region} (specifically, $t_{under-ridge}$ and $t_{pre-ridge}$)	Number of tracked frames for the chosen region*1/fps	s
v_{cell}	$\frac{\sqrt{[(x_{i+1} - x_i)^2 + [(y_{i+1} - y_i)^2]}}{t}$	m/s
v_{fluid}	From CFD simulations	m/s
U_{slip}	$ v_{fluid} - v_{cell} $	m/s
Average Strain	$\bar{\varepsilon} = (H_r)_{avg} / D_{cell}$	-
BBH Force	$F_{BBH} = \frac{3}{2} D_{particle}^2 \sqrt{\pi \rho \mu} \int_{t_0}^t \frac{1}{\sqrt{t - \tau}} \frac{dU_{slip}}{d\tau} d\tau$	N
BBH Force Rate	$F_{BBH} / t_{pre-ridge}$	N/s
Stokes Drag Force	$F = 3 \pi \mu D_{cell} v_{cell}$	N
Strain rate	$\dot{\varepsilon} = (H_r)_{avg} / (t_{under ridge} \cdot D_{cell})$	s ⁻¹

Supplementary Table 2: A summary of hydrodynamic parameters used for PCA and multi-variate analysis

Supplementary Figures

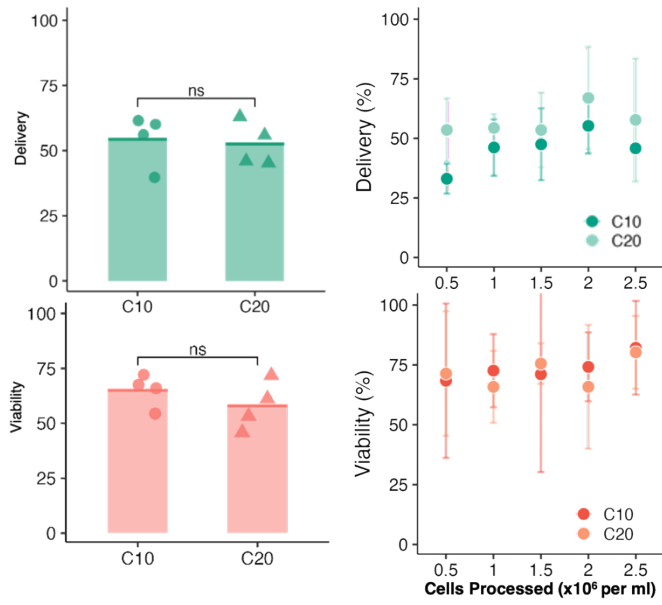


Supplementary Fig 1 | **Deformation of PDMS channels with increasing flow rates:** The three insets in top row show how deformation changes with channel designs. As discussed in the paper, C10 represents devices with an aspect ratio (AR = width:height) of 2:1, C05 represents devices with AR=10:1, and C01 represents AR=20:1. The bottom row shows deformation modelling for C10 fitting Gervais Model (M0) and second order functions to identify the accurate height profile (shown in the last subplot)

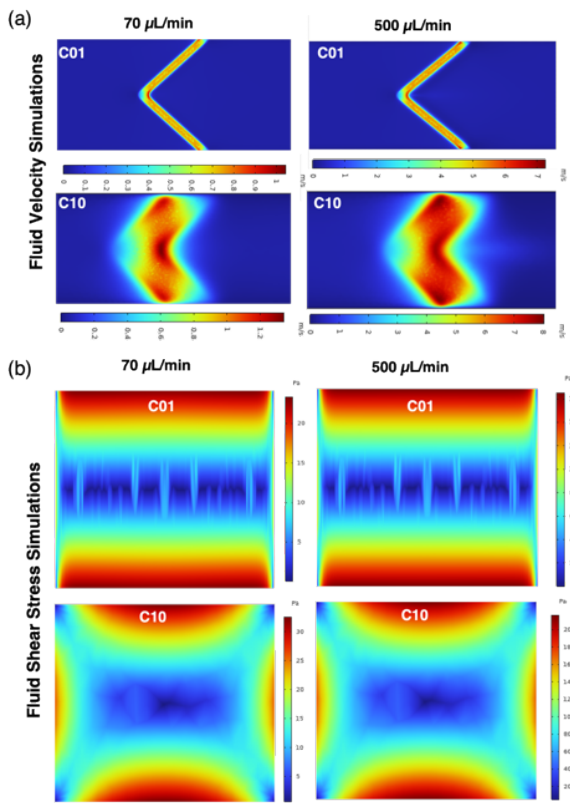


Supplementary Fig 2: Staining indices for both T-cells and B16F10 computed from flow cytometry data

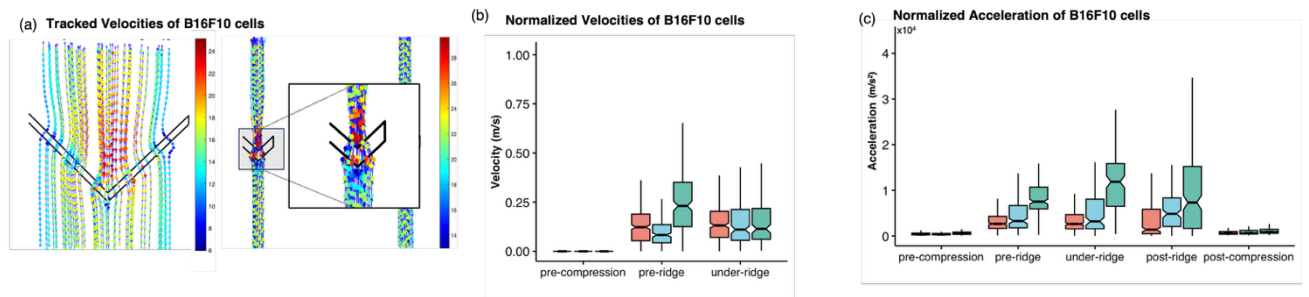
(a) Changes in mechanoporation metrics with scaling of channels (b) Temporal variation of mechanoporation metrics across C10 and C20



Supplementary Fig 3: A comparison of 10-channel design C10 scaled up to 20 channels of same dimension and operated at 2 times the flow rate to balance the throughput from both devices and flow dynamics per channel. C10 was operated at 250 μ L/min, C20 was operated at 500 μ L/min



Supplementary Fig 4: (a) shows fluid velocity simulation (b) shows the flow resistance measurements as simulated using COMSOL for the different designs (c) shows simulated fluid shear stress

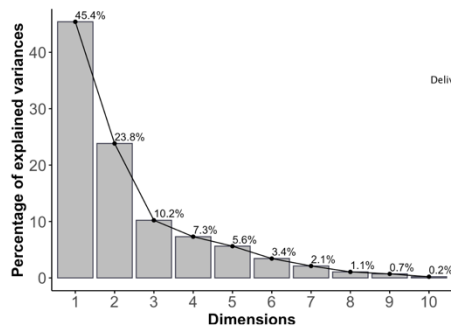


Supplementary Fig 5 | Tracking summary (a) shows heatplots of tracked velocity in C01 and C05 (b) shows normalized velocities (c) shows normalized acceleration magnitude

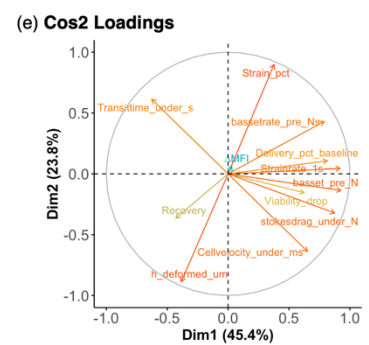
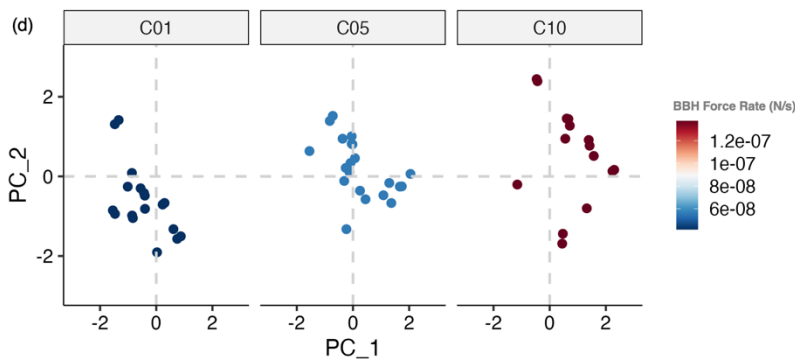
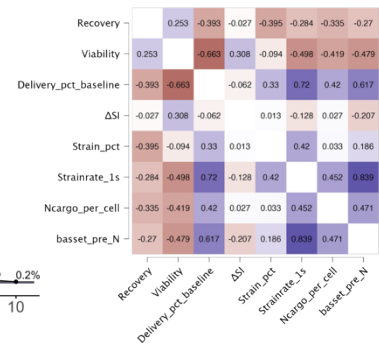
(a) Table of loading contributions

Variable (units)	PC.1	PC.2
Strain Rate (1/s)	15.55	0.07
Basset Force (N)	15.77	0.65
Delivery (%)	12.22	0.41
Viability Drop (%)	7.19	0.84
Recovery (%)	3.38	4.65
Stokes Drag Force (N)	14.08	3.62
Average H_r , deformed (μm)	2.71	27.47
Average Strain (%)	2.61	28.24
Cell velocity under ridge (m/s)	7.81	14.26
Transit time under ridge (s)	7.22	13.17
ΔMFI (a.u.)	0.02	0.14
Basset Force Rate (N/s)	11.44	6.49

(b) Scree Plot



(c) Correlation plot



Supplementary Fig 6 | PCA analysis with multiple mechanistic variables (a) Individual loadings of the selected variables after optimizing variable subsets for best KMO and silhouette scores. Dark green colour denotes strong contribution to the principal component. (b) Scree plot showing relative variance explained by computed PCs (c) Pearson Correlation analysis between multiple variables used for PCA modelling (d) Samples colored by BBH force rate showing a key distinguishing parameter amongst designs with varying widths. (e) Cos 2 loadings of each variable on PC1 and PC2.