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Probing Fatigue Failure of Human Red Blood Cells in Health and Disease

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Abstract

Human red blood cells (RBCs) are subjected to dynamic and cyclic loads when they traverse through the cardiovascular system during their normal lifespan of approximately 90 to 120 days. Abnormal conditions such as cold storage and pathologies can affect their capability to withstand the cyclic stressing in blood circulation, leading to undermined biological functions and shortened lifespan. A quantitative measure of the dynamic behavior of RBCs under the cyclic loads, can elucidate the fatigue process of cell membranes during blood circulation. We established a new experimental approach based on amplitude modulated electrodeformation strategy in a microfluidic platform. This approach allows generation of monotoic and cyclic loads in the forms of mathematically defined waveforms or arbitrary loading profiles for the study of fatigue failure in plasma membranes of cells. Deleterious effects of cyclic loads were quantified by the characteristic fatigue features and membrane biomechanics for both healthy and abnormal RBCs. The results showed strong correlations between cellular physiological state and fatigue life. This approach provides an accelerated life testing for RBCs and can be extended to other cell types.