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Cell-substrate specific adhesion model regulated by substrate stiffness

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Summary

Cell-substrate interfacial interplay plays a key role in many fundamental aspects of mammalian physiology. Recent progresses in related experiments concerning cell interactions with extracellular matrix have demonstrated that substrate rigidities can exert a remarkable influence on cell adhesion and spreading dynamics. For example, it has been reported that cell-substrate adhesion strength usually rises monotonically with Young's modulus of underlying elastic substrates and eventually achieves the strongest adhesion on rigid substrates such as glass, and that cell spreading area takes on a growing trend with the increase in substrate hardness and finally reaches a plateau when the stiffness exceeds the order of MPa. The inherent biophysical mechanism regarding the aforementioned interesting phenomena, however, still remains elusive to a great extent. Starting from the known Bell-Dembo's models, we developed a mechano-chemical coupling framework to investigate cell-substrate interfacial adhesion strength mediated by substrate rigidities, in which the effects of integin receptor-ligand specific interaction, substrate elasticity and non-specific repulsive potential originating from steric stabilization of glycocalyx layers were fully taken into account. The quantitative dependence of cell specific adhesion strength on elastic modulus of extracellular substrates was deduced analytically by employing mechanical equilibrium conditions between plasma membranes and flexible substrates. Additionally, the process of steady-state cell spreading on elastic substrates was studied with the aid of the traditional wetting theory, which agreed well with existing experimental data. This proposed model may provide a valuable guide for investigating the effect of mechanical properties of substrates on cell adhesion and spreading.