Modern microscopic techniques have led to the discovery of a multitude of anomalous diffusion processes which show significant deviations from the laws of Brownian motion in a variety of animate and inanimate systems. The nature of anomalous diffusion is non-universal and may originate from numerous physical processes. There exist a variety of theoretical models sharing the same non Fickian Mead Squared Displacements, including continuous time random walk models for particle motion in heterogeneous environments, and stochastic processes with distributed or time varying diffusion coefficient. Moreover, fractional Brownian motion and fractional Langevin equation of motion with a power-law correlated noise can describe the dynamics of particles in viscoelastic media such as the cell cytoplasm. We establish and investigate a paradigm anomalous diffusion process governed by an underdamped Langevin equation with an explicit time dependence of the system temperature and thus the diffusion and damping coefficients. We show that for this underdamped scaled Brownian motion (UDSBM) the overdamped limit fails to describe the long time behaviour of the system and may practically even not exist at all for a certain range of the parameter values. Thus persistent inertial effects play a non-negligible role even at significantly long times. From this study a general questions on the applicability of the overdamped limit to describe the long time motion of an anomalously diffusing particle arises, with profound consequences for the relevance of overdamped anomalous diffusion models. We elucidate our results in view of analytical and simulations results for the anomalous diffusion of particles in free cooling granular gases.