The Jahn-Teller effect in the lowest excited states of the nitrate radical NO$_3$ remains poorly understood. In this paper, we examine the first excited state, $\tilde{A} 2E''$, in a joint experimental and theoretical study. The forbidden $\tilde{A} 2E'' \leftrightarrow \tilde{X} 2A_2$ transition is recorded by Near Infrared Cavity Ringdown Spectroscopy (CRDS) at medium resolution from 6000 to >10,000 cm$^{-1}$, extending and refining our preliminary results. We observe over 30 major vibronic bands, most with resolvable rotational structure. Tentative assignments are made on the basis of high level EOMIP-CCSD(T) calculations of the vibronic Hamiltonian, which includes up to quartic terms. Our results indicate that the $\tilde{A}$ state undergoes static Jahn-Teller distortion, with strong vibronic coupling among both degenerate modes and the symmetric stretch. The Jahn-Teller effect in NO$_3$ appears to be complex and unusual, and remains a difficult but fascinating challenge.