Hydrogen bonding (HB) contributes significantly to the stability of the helical duplex structure of DNA. However, the quantum nature of HBs in these systems is usually not taken into account. In this study we evaluate the effect of nuclear quantum effects (NQEs) on the binding free energies of the Watson-Crick base pairs, using an \textit{ab initio} path-integral based thermodynamic integration method. We find that NQEs \textit{strengthen} the binding of both Adenine-Thymine and Cytosine-Guanine pairs at room temperature. At a lower temperature, however, NQEs can weaken the binding, revealing an interesting temperature dependence of NQEs in DNA binding. Analysis of the quantum kinetic energies explains the strengthening and weakening effects as a balance between competing quantum effects associated with low frequency bond bending and high frequency bond stretching. The delicate changes in binding energy due to NQEs can affect the melting temperature of DNA and could also provide theoretical insights on the isotope fractionation factors of DNA base pairs. Our study establishes a quantitative description of NQEs on the binding of DNA base pairs that could also be helpful in understanding similar H-bonded biomolecule systems.