Exercise effects in a virtual type 1 diabetes patient: Using stochastic differential equations for model extension

The use of virtual patients for in silico testing of control algorithms for an artificial pancreas is growing. It is an easy, fast and low-cost alternative to pre-clinical testing. To simulate the everyday life of a type 1 diabetes (T1D) patient a simulator must be able to take into account physical activity. Exercise constitutes a substantial challenge to closed-loop control of T1D. The effects are many and depend on intensity and duration and may be delayed by several hours. In this study, we use a model for the glucoregulatory system based on the minimal model and a previously published extension incorporating exercise effects on insulin and glucose dynamics. Our model is constructed as a stochastic state space model consisting of a set of stochastic differential equations (SDEs). In a stochastic state space model, the residual error is split into random measurement error and misspecification noise. The latter of the two can be used to pinpoint model deficiencies or unknown influential factors during the development of the model. The model is thus built on the basis of physiological knowledge of the system combined with information from observed data. Model parameters are estimated on clinical data from a study including exercise bouts of 20 minutes performed on 12 T1D patients treated with continuous subcutaneous insulin infusion. The predictive abilities of the model are investigated. In conclusion, this study illustrates the advantages of using SDEs in the development of an extended glucoregulatory model including effects of exercise suited for in silico testing.