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Identification of factors influencing the carb-counting error in the type 1 diabetes management

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Background and aims: Carb-counting is widely used in standard type 1 diabetes (T1D) insulin therapy to calculate meal insulin bolus size. Errors can be very critical: underestimation of meal carbohydrates (CHO) content can lead to hyperglycemia, while CHO overestimation can cause hypoglycemia. The aim of this work is to quantitatively investigate which factors, related to patient and meal, affect carb-counting error most.

Materials and methods: Data come from a study involving 50 T1D adults that estimated the CHO amount of their consumed meals in 3 days of real life conditions. For each meal, the reference value of CHO amount was calculated by a dietitian and the carb-counting error assessed accordingly. Available patient's and meal's variables included subject's level of education, duration of insulin treatment, age, body weight, meal’s CHO, lipids amount, energy content, proteins amount, fiber content and type (breakfast, lunch, dinner and snack). A multiple linear regression model approach, using as independent variables all the variables previously selected and as dependent variable the signed carb-counting error, is developed. The most important regressors were then identified using stepwise variable selection. The stopping rule used is an F-test with p-value for entering set at 0.05 and p-value for removing set at 0.1.

Results: The coefficient of determination $R^2$ of the full linear model is 0.311. This means that the involved regressors explain about the 30% of the variance of the carb-counting error. The performed F-test allows the rejection ($p<0.05$) of the null hypothesis $H_0$, i.e. *all the slopes of the linear model are equal to 0*, proving that at least one of the regressors is needed to explain the response. The following stepwise variable selection procedure starts with a model with no regressors and, at each step, adds the variable that provides the best fit. At step 1 the variable CHO is added ($p$-value<0.00001, $R^2=0.273$), while the meal’s type is added at step 2 ($p$-value<0.00001, $R^2=0.304$). This suggests that meal’s CHO and type are the most important predictors of carb-counting error and, together, they explain almost the total variance of the error explained by the full linear model ($R^2=0.304$ vs $R^2=0.311$). At step 3 a patient-specific variable, i.e. the body weight, is added to the model ($p$-value=0.0472, $R^2=0.308$). No other variables are added: this means that no strong correlation exists between the other variables and the error.

Conclusion: Meal’s CHO and type are the most important factors that influence the carb-counting error. Future developments of the study can be the extension of the model by non-linear terms and its incorporation in T1D patient computer simulators aimed at performing realistic in silico clinical trials.

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