SUMMARY

Estimation of metabolic equivalent values of daily activities using heart rate monitor without calibration of individuals

Yuko Caballero

Estimating human physical energy expenditure (EE) is crucial both for deciding the quantities of food one should consume in a daily basis and knowing physical activity requirement to prevent lifestyle diseases and promote one's health. The doubly labeled water method is known to be the most accurate for estimating total EE. However, it is not feasible for daily use because it needs time and cost. In addition, the method does not provide EE produced by physical activities in the specific time range. Therefore, an accurate measure of daily activities, especially its duration and metabolic intensity, would be crucial both in assessing individual activity levels and in evaluating the independent effects of the daily activities on health status in an epidemiological study.

Recently, accelerometers and other devices with a variety of algorithms for estimating EE have been expanded in the market. However, accelerometer cannot measure specific activities, like ascending the stairs and carrying packages, at present. On the other hand, a heart rate (HR) monitor is a reasonable device and many products with HR monitors are being developed. HR during physical activity has a strong correlation with the level of physical activity intensity and is associated with physical fitness. Therefore, HR monitors can predict EE during exercise if the prediction equation is established for each individual. However, this method utilizing the prediction equation is not useful for a large-scale study because it has to be calibrated by measuring EE with HR for each individual. Furthermore, the accuracy of the model decreases in low-intensity activities, and HR differs depending on age, sex, and the level of physical fitness. Therefore, these characteristics are key obstacles that prevent us from accurately estimating EE.

Metabolic equivalent (MET) is an index of physical activity intensity, calculated as a ratio of metabolic rate during an activity to metabolic rate at rest, and serves as a normalized index of physical activity intensity in each individual. Therefore, it would be convenient if METs could be calculated directly from measured HR values, without the need for recalculation utilizing EE. Furthermore, it is useful for applying METs to the recommendation of daily physical activities.

Percent HR reserve (%HRR) has been reported to be a major predictor for estimating EE. It is a relative value, assuming that HRmax is 100% and resting HR is 0%; thus, it reflects one’s relative exercise intensity, minimizing individual differences.

The aim of this study was, therefore, to develop simple multiple-regression models for estimating METs of daily activities by including parameters such as %HRR and resting HR in adults.

The linear tendency between HR and EE is known to be observed only from 20% to 75% of %HRR. Therefore, firstly, I developed predictive equations to estimate the metabolic equivalents (METs) of daily activities using the range of 20% to 75 %HRR for the aim of using combined devices with accelerometer. For easy estimation of METs without body composition measurement, I developed two models, using multiple regression analysis applying stepwise method, and linear regression in which intercept and slope were predicted from one’s parameters. The smallest mean percent error (MPE) was observed in the multiple regression with body composition parameters and the MPE was 0.3%.

Secondly, I developed one equation, x axis is %HRR and y axis is METs, that encompassed low to high intensity activities. When compared among models of linear regression, quadratic equation, cubic equation, and logarithmic functions, the linear regression showed the smallest error of all. I also considered setting the cutoff point to divide into two equations. However, the prediction without a cutoff showed the smallest MPE.

In the next step, I developed predictive models, one with BMI and another with weight and height, using brute force method from %HRR to METs. The model with the minimum value of Akaike’s Information Criterion (AIC), which gives the best fit of all models, deleting redundant variables was selected. In the result, two models with the independent variables, one with %HRR, resting HR, and height, another with %HRR, resting HR, and height were selected. %HRR was the highest contributor to the model (standardized β = 0.944) among all variables. The standardized β of resting HR in the model with %HRR was −0.080 and it showed smaller contribution to the model. Moreover, the result showed that standardized β values of sex and height were small: 0.048 and 0.064, respectively. The total MPE of all activities was 2.4% (SD 23.1%) in the model including %HRR, resting HR, and height and it was the smallest of all. However, it showed an approximate 2% decrease in MPE during low intensity activities such as operating a mobile phone and PC work, compared to the model with only %HRR, therefore it suggested the model with only %HRR was enough to estimate METs with relatively small prediction errors.

Lastly, I validated these models by comparing them with other previous studies, HR algorithms and combined devices of accelerometer and HR. In the results, the present study showed small RMSEs of METs, at the same level as Crouter's study using two equations, as well as previous reports that used tri-accelerometer and/or HR. Moreover, ascending and descending stairs showed relatively small MPEs compared to other methods using accelerometers. This result might be mainly because METs was predicted directly, instead of EE.

This study revealed that %HRR is a large contributor and it suggests that %HRR can simply predict one's METs accurately. On the other hand, the result showed that resting HR and other variables were small contributors compared to %HRR in contrast to my expectation.

The result of the study, simple prediction of METs from HR without calibration can be useful for applying wearable devices for estimating EE more accurately.