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The simple method for predicting metabolic equivalents using heart rate in patients with cardiovascular disease

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Exercise capacity is an important index to assess exercise stress in cardiac rehabilitation patients. Exercise capacity is generally expressed in units of metabolic equivalents (METs) calculated during cardiopulmonary exercise testing (CPX) using a ventilatory expired gas analysis system. While guidelines of academic association recommend conducting CPX to calculate METs [1,2], CPX induces heavy exercise stress and requires the use of equipment such as a cycle ergometer and treadmill, which is not always feasible in frail elderly patients or those with unstable circulation dynamics. The present study explored the possibility of predicting METs during exercise from heart rate (HR) of patients with cardiovascular disease.

A total of 251 patients aged ≥18 years underwent CPX at the cardiac rehabilitation center of our hospital on an outpatient basis between April 2012 and August 2017. Of these, 243 patients with ischemic heart disease, valvular disease, and/or heart failure were included in this study. Patients with atrial fibrillation, implanted cardiac pacemakers or ventricular assist devices, and a history of orthopedic conditions or cerebrovascular diseases were excluded. Background factors including age, sex, body mass index (BMI), diagnosis, left ventricular ejection fraction (LVEF), brain natriuretic peptide (BNP), and medication use (e.g., β-blockers, angiotensin converting enzyme inhibitors, angiotensin II receptor blockers (ACEIs/ARBs), and diuretics) were extracted from clinical records as parameters. CPX was conducted using a cycle ergometer (Strength Ergo 8; Mitsubishi Electric Engineering Co., Ltd., Tokyo, Japan) with a ventilatory expired gas analysis system (Cpex-1; Inter Reha, Tokyo, Japan). Exercise intensity was increased by 10 or 20 W/min. HR_{rest} was defined as the lowest HR recorded while seated on the cycle ergometer for 3 min, and HRs measured every minute after the start of CPX were used as $HR_{absolute}$. METs corresponding to HR_{rest} and $HR_{absolute}$ were examined.

The results of CPX from 243 patients yielded 2048 data sets for analysis. The mean age was 58.7 ± 12.6 years, 74.5% were men, and the median LVEF and BNP were 57.6 ± 15.5% and 75.5 (interquartile range, 36.3–152.6) pg/mL, respectively; 66.8% of patients used β-blockers (Table 1). Relationships between HR parameters and METs are shown in Fig. 1. Significant positive correlations were observed between METs

Table 1
Clinical characteristics.

	$n = 243$	(Minimum–maximal)
Age (years)	58.7 ± 12.6	(26–79)
Male (%)	74.5	
BMI (kg/m^2)	23.8 ± 3.90	(16.4–38.9)
LVEF (%)	57.6 ± 15.5	(10.3–89.6)
Diagnosis (%)		
Ischemic heart disease	48.9	
Cardiac surgery	27.5	
Heart failure	23.6	
BNP (pg/ml)[a]	75.5 (36.3–152.6)	(5.4–2154.2)
HR rest (beats/min)	69.0 ± 11.1	(44–101)
Peak HR (beats/min)	130.1 ± 21.80	(73–202)
Peak VO_2 (ml/kg/min)	20.3 ± 5.4	(8.3–43.3)
Medications (%)		
β-Blockers	66.8	
ACEIs/ARBs	68.1	
Diuretics	35.7	

Mean ± SD; BMI = body mass index; BNP = brain natriuretic peptid; HR = heart rate; ACEI = angiotensin converting enzyme inhibitor; ARB = angiotensin receptor blocker.
[a] Median (interquartile range).

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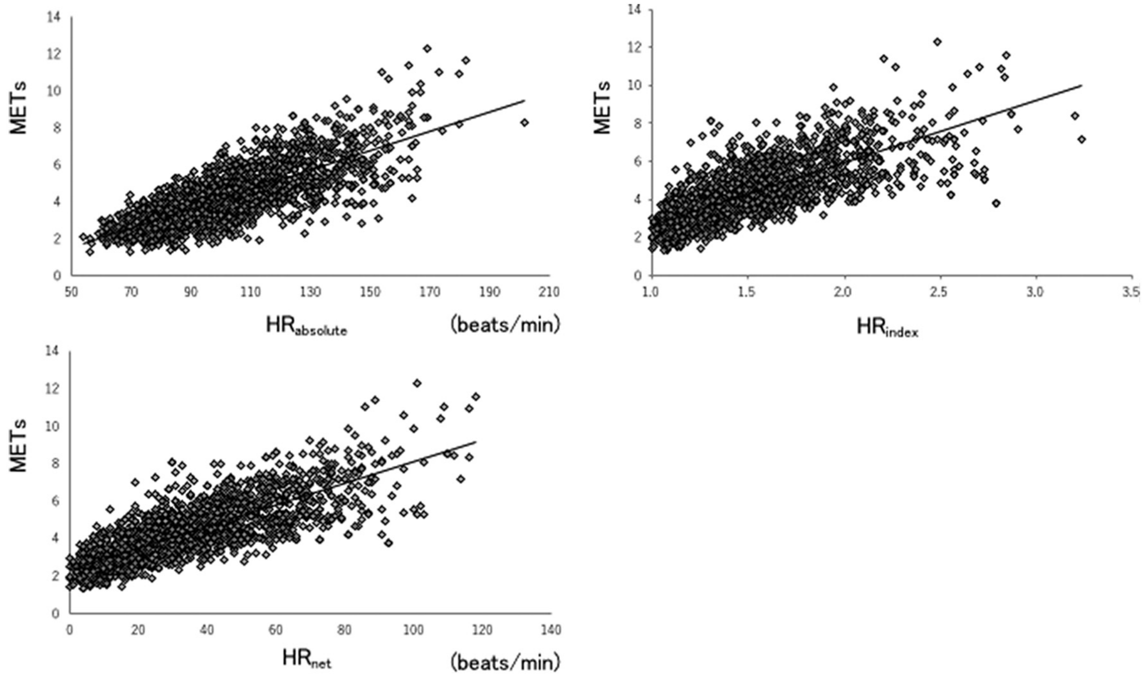

Fig. 1. Relationships between HR parameters and METs. Upper left: Relationship between METs and $HR_{absolute}$. Lower left: Relationship between METs and HR_{net}. Upper right: Relationship between METs and HR_{index}.

during exercise and $HR_{absolute}$ ($r = 0.740$), HR_{net} ($HR_{absolute}/HR_{rest}$) ($r = 0.799$), and HR_{index} ($HR_{absolute} - HR_{rest}$) ($r = 0.764$) ($p < 0.001$, respectively). A simple linear regression analysis was performed with independent variables of each HR parameter, yielding the following prediction formulae: $\text{METs} = 0.05 \times HR_{absolute} - 1.0$ (adjusted $R^2 = 0.584$) for $HR_{absolute}$; $\text{METs} = 0.05 \times HR_{net} + 2.1$ (adjusted $R^2 = 0.638$) for HR_{net}; and $\text{METs} = 3.2 \times HR_{index} - 0.7$ (adjusted $R^2 = 0.548$) for HR_{index} ($p < 0.001$, respectively). Subgroup analyses were performed for age (young vs. elderly), sex (men vs. women), BMI (<25 kg/m^2 vs. ≥25 kg/m^2), exercise type (10 W vs. 20 W), and the use of β-blockers. Although the regression equations were different for $HR_{absolute}$ and HR_{index} in each subgroup analysis, the regression equation for HR_{net} had the minimum variance for the slope and intercept, suggesting that METs could be predicted using $0.05 \times HR_{net} + 2$.

The results of the present study showed that HR parameters could be used to predict METs during exercise. HR_{net} was least influenced by background factors and β-blocker use, suggesting that METs during exercise can be roughly predicted using a formula of $0.05 \times HR_{net} + 2$. This formula could be useful for predicting METs during exercise from HR alone, without using specialized equipment in clinical settings.

There are some limitations in this study. First, HR_{rest} may have affected the prediction formula. Future studies are needed to investigate whether the prediction formula calculated separately by HR_{rest} affects R^2 values. Second, since the present study used a cycle ergometer for CPX, the results of our analysis should be validated with data obtained using a treadmill. Third, when applying the prediction formula, if HR_{net} is 0, estimated METs would be 2; therefore, METs <2 cannot be predicted. However, activities corresponding to METs <2 are considered resting physical activities (e.g., reading in a lying or seated position) [3], and thus, no potential issues resulting from this are likely to limit the application of this formula.

The present study was the first to explore the possibility of predicting METs from HR_{rest} and $HR_{absolute}$ in patients with cardiovascular disease. METs during exercise could be predicted by $0.05 \times HR_{net} + 2$, regardless of age, sex, BMI, or the use of β-blockers that affect HR. This method could be useful for estimating METs in cardiac rehabilitation patients, as it requires no specialized equipment and enables instant feedback to patients.

Conflict of interest

The authors have no conflicts of interest to report.

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