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RESEARCH

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Basal metabolic rate correlates with excess postexercise oxygen consumption across different intensities

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Abstract

Background Both the basal metabolic rate (BMR) and excess postexercise oxygen consumption (EPOC) can be influenced by physical training and are associated with body composition and aerobic capacity. Although a correlation between the two is expected, this relationship has not been explored. Our hypothesis is that a higher BMR is correlated with lower EPOC.

Methods Fifty-four healthy participants with a mean age of 33 years were enrolled and instructed to visit the exercise laboratory five times within a 3-week period. These visits included one for the BMR measurement, one for the incremental exercise test (INC), and three for the constant work rate (CWR) test at low (35% of the maximal work rate, 15 min), moderate (60%, 10 min), and high intensities (90%, 4 min). The CWR tests were conducted at low, moderate, and high intensities in random order. After each CWR test, the EPOC and the ratio of EPOC to oxygen consumption during exercise (OC) were calculated. Venous blood samples were collected immediately to assess the blood lactate concentration (BLa).

Results The EPOC, EPOC/OC, and BLa increased with increasing intensity of the CWR tests. BMR exhibited an inverse correlation with EPOC/OC across the three CWR settings with correlation coefficients -0.449 in low ($p = 0.003$), -0.590 in moderate ($p = 0.002$), and -0.558 in high intensity ($p < 0.001$). In the stepwise regression analysis, the BMR emerged as the most significant predictor of EPOC/OC compared to the BLa, age, BMI, and various parameters derived from the INC and CWR CPET. Additionally, coupling EPOC/OC with CWR exercises of identical duration and relative intensity provides a viable method for interindividual comparisons.

Conclusions The BMR is a major predictor of EPOC/OC and demonstrates a negative linear correlation across various CWR intensities. This study improves the understanding of the physiological link between BMR and EPOC and introduces an applicable approach for utilizing EPOC in future research.

Keywords Lactate, Peak oxygen consumption, Aerobic capacity, Anaerobic threshold, Body composition

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Background

The basal metabolic rate (BMR) and excess postexercise oxygen consumption (EPOC) play pivotal roles in the regulation of energy balance. The BMR represents the baseline energy expenditure required to maintain bodily functions, which constitutes approximately 60–70% of daily energy expenditure [1] whereas the EPOC refers to increased energy expenditure during the recovery period following exercise [2–4], which helps compensate for additional energy expended during exercise.

The BMR is influenced by factors such as lean body mass, age, sex, weight, height and BMI [5, 6]. On the other hand, several factors influence the extent and duration of EPOC. The intensity demonstrates a positive curvilinear relationship with the EPOC magnitude, while the relationship with duration and EPOC is linear, especially when the intensity exceeds 50–60% VO_{2max} [7]. Additionally, body composition, including body fat and muscle mass, training status, and sex, are associated with EPOC [8].

Intriguingly, both the BMR and EPOC can be influenced by physical training [9–11] and are associated with similar individual physical traits, such as body composition [8, 12–14] and aerobic capacity [13, 15]. Logically, there should be a correlation between the BMR and EPOC, and this relationship may be linked to exercise intensity as EPOC is primarily determined by exercise intensity [7]. According to our literature search, no published studies have explored the relationship between these two variables.

Accordingly, we postulated that individuals with a higher BMR would have a lower EPOC production. In this study, we conducted a comprehensive investigation of the relationship between EPOC and normalized EPOC against oxygen consumption during exercise (OC), blood lactate levels (BLa), BMR, and various anthropometric and physiological variables. To test these associations, we implemented a finely tuned constant-work-rate (CWR) exercise testing protocol encompassing low, moderate, and high intensities, with a fixed intensity and duration for each level. Our hypothesis was that individuals with a higher BMR would exhibit lower EPOC per OC (EPOC/OC) under identical durations and relative intensities in CWR testing.

Methods

Participants and experimental protocol

Fifty-four healthy participants aged 20–50 years were recruited through convenience sampling. Individuals with a medical history of cardiopulmonary disease were excluded. The Institutional Review Board of Chang Gung Memorial Hospital approved the experimental protocol (Approval No. 102–2960B). All participants provided written informed consent after receiving oral and printed explanations of the experimental procedures. The study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki.

Each participant was instructed to visit the exercise laboratory five times within a 3-week period. These visits included one for the BMR measurement, one for incremental cardiopulmonary exercise testing (CPET) on a cycle ergometer (Ergoselect 150P; Ergoline, Germany), and three for the CWR CPET. Comprehensive demographic information, including sex, age, height, weight, and body mass index (BMI), was collected. The CWR tests were conducted at low, moderate, and high intensities in random order using a random number generator. At least one-day intervals were allowed between each of the four exercise tests. Venous blood was sampled to determine the blood lactate concentration (BLa), and immediate evaluation of EPOC was conducted after each CWR test. The testing protocol and timing of venous sampling are summarized in Fig. 1.

Basal metabolic rate measurement

The participants' BMR was determined using a cardiopulmonary function tester (MasterScreen CPX; Cardinal Health, Germany). BMR assessments were conducted in the morning following a 12-h fasting period, with participants refraining from smoking for at least 1 h before the test. Each participant slept in a single room with the temperature controlled at approximately 24 degrees Celsius and the humidity maintained at approximately 55 ~ 60%. The BMR measurements were performed between 8 and 10 AM. Throughout the procedure, participants were required to remain motionless and refrain from speaking. The female participants were scheduled for measurements outside their menstrual period. Before each test, the indirect calorimetry (IC) systems were prewarmed for a minimum of 30 min and calibrated according to the manufacturer's instructions. Oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$) were continuously recorded for 20 to 30 min until steady-state equilibrium was achieved and maintained for at least 5 min. The measurements were considered acceptable when the coefficient of variation of $\dot{V}O_2$ was < 10%; the average value for the last 60 s was used. A facemask, open-circuit spirometry setup, and breath-by-breath measurements were employed. To calculate the BMR, the $\dot{V}O_2$ and $\dot{V}CO_2$ values from the last min were averaged. The abbreviated Weir equation was used, with BMR (kcal/day/kg) calculated as follows: [$\dot{V}O_2$ (L/min/kg) × 3.94 + $\dot{V}CO_2$ (L/min/kg) × 1.11] × 1440 [5].

Cardiopulmonary exercise testing

Each participant was instructed to abstain from exercising for 24 h before each exercise test. The incremental exercise test (INC) consisted of 1 min of unloaded pedaling,

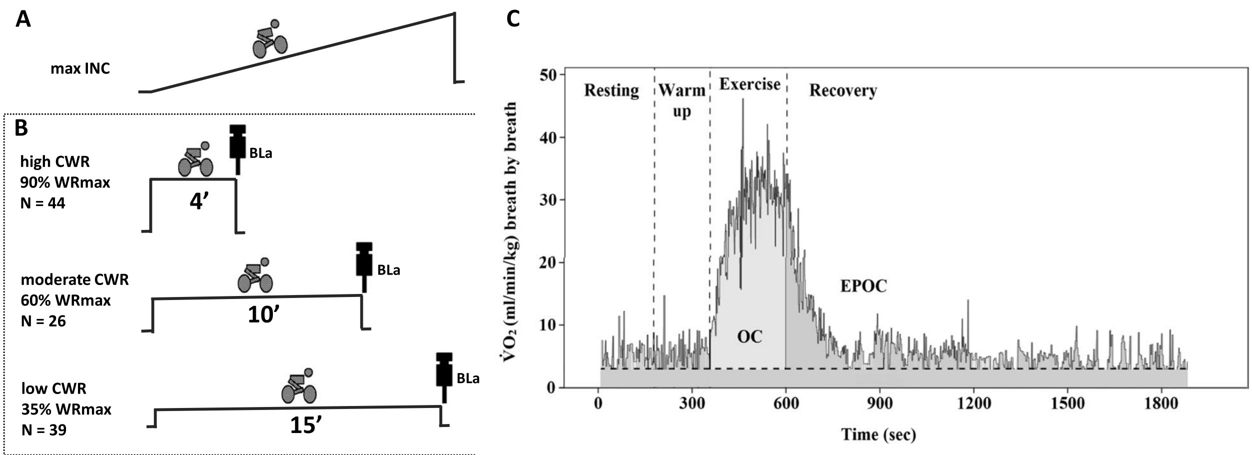

Fig. 1 Each participant underwent one incremental (INC) cardiopulmonary exercise test on a cycle ergometer (**A**) and three constant work rate (CWR) tests at low, moderate, and high intensities in random order. Immediate evaluation of EPOC and blood lactate concentration (BLa) through venous blood sampling were conducted after each CWR test (**B**). **C** shows the high-intensity CWR test conducted during one of the actual experimental measurements. The OC represents oxygen consumption during exercise, whereas the EPOC represents excessive postexercise oxygen consumption

followed by a continuous increase in the work rate of 15 W/min until exhaustion, determining the maximal work rate. The maximal $\dot{V}O_2$ was defined based on the following criteria: (I) $\dot{V}O_2$ increased by < 2 mL/kg/min over at least 2 min, (II) heart rate exceeded 85% of its predicted maximum, (III) the respiratory exchange ratio exceeded 1.15, or (iv) other symptom/sign limitations [16]. Subsequently, each participant underwent three CWR exercise tests: 15-min low-intensity CWR at 35% of the maximal work rate (LC), 10-min moderate-intensity CWR at 60% of the maximal work rate (MC), and 4-min high-intensity CWR at 90% of the maximal work rate (HC) [17]. The selection of low (35%), moderate (60%), and high (90%) CWR intensities was based on three zones: below ventilatory threshold 1 (VT1), between VT1 and VT2, and above VT2 [18, 19]. In the majority of healthy people, VT1 occurs at 40–60% of the maximal $\dot{V}O_2$ [20], and VT2 occurs within the range of 61.3% to 85.4% of the maximal $\dot{V}O_2$ [21, 22]. Minute ventilation (V_E), oxygen uptake ($\dot{V}O_2$), and carbon dioxide production ($\dot{V}CO_2$) were measured breath by breath using a computer-based system (MasterScreen CPX, Cardinal Health, Germany). The anaerobic threshold (AT) was determined primarily by the V-slope method and verified based on the following ventilatory criteria: (i) departure from linearity for $\dot{V}CO_2$ against $\dot{V}O_2$, (ii) an increase in the V_E-$\dot{V}O_2$ ratio without a corresponding increase in the V_E-$\dot{V}CO_2$ ratio and (iii) an increase in the end-tidal tension of oxygen without a corresponding decrease in the end-tidal tension of carbon dioxide [23]. The VAT was identified by two independent reviewers. The heart rate (HR) was determined from the RR interval of a 12-lead ECG (CardioSoft, GE, Milwaukee, WI, USA). Arterial blood pressure was measured every 2 min using an automatic blood pressure system (Tango; SunTech Medical, UK), and arterial O_2 saturation was continuously monitored using finger pulse oximetry (model 9500; Nonin Onyx, Plymouth, MN, USA). End-exercise values were determined as the average of the final 15 s of exercise for both CWRs ($\dot{V}O_{2end}$ and HR_{end}) and INCs.

Measurement and computation of excess postexercise oxygen consumption and oxygen consumption during exercise

The participant was instructed to remain seated on the cycle ergometer for a 30-s active recovery, during which they pedaled at a comfortable cadence of 30–60 RPM at 0 watts. Afterward, they were moved to a supine position to continue with the gas analysis measurements. The EPOC was computed by summing the difference between the postexercise $\dot{V}O_2$ measured breath by breath and the basal $\dot{V}O_2$ established in the previous BMR measurement and then multiplied by the duration of the corresponding breath. The $\dot{V}O_2$ was recorded for 20 min during the recovery phase [8, 24]. Similarly, the OC was computed by summing the difference between the during-exercise $\dot{V}O_2$ measured via breath by breath and the basal $\dot{V}O_2$ and then multiplied by the duration of the corresponding breath (Fig. 1). The formula is presented as follows.

$$\text{EPOC or OC } = \sum(\dot{V}O_2 \text{ measured breath by breath} - \text{basal } \dot{V}O_2 \text{ established in BMR measurement}) \times \text{duration of the corresponding breath}$$

Blood lactate measurement
Venous blood was sampled mostly from the antecubital vein or, in a few cases, from the dorsal interosseous metacarpal vein for the BLa assay immediately (30–60 s) after the end of the CWR exercise tests. The samples were collected in NaF/K3EDTA tubes and placed on ice. Whole blood was centrifuged within 90 min to obtain plasma, which was subsequently stored at 4 °C. BLa was measured using an enzymatic method within 14 days of sampling (Beckman DXC880i).

Statistics
The data are presented as the mean ± standard deviation and were analyzed using IBM SPSS Statistics 22.0. Multivariate forward linear stepwise regression analyses were also conducted to determine the parameters that correlated with EPOC/OC (the dependent variable) in the LC, MC, and HC groups. The independent variables included parameters derived from the CPET at the INC and the corresponding CWR, as well as anthropometric variables (i.e., sex and the parameters listed in the left column of the correlation matrix in the supplementary data). Independent T test was used to compare the BMR between sexes. One-way ANOVA with Bonferroni post hoc tests was performed to compare EPOC, OC, EPOC/OC, BLa, $\dot{V}O_{2end}$ and HR_{end} among the LC, MC and HC CWRs. The criterion for statistical significance was a p value < 0.05.

Results
Of the total 54 healthy individuals (31 males and 23 females) who were recruited for the present study and completed the INC test, 42, 24, and 37 completed the LC, MC, and HC exercise tests, respectively. Table 1 presents the basic information and cardiopulmonary fitness status of the study participants. The anthropometric data and cardiorespiratory fitness showed no significant differences among the three conditions. Notably, the BMR was significantly different between male and female participants (28.8 ± 5.5 vs. 25.5 ± 4.7 kcal/day/kg, $p = 0.033$ by independent t tests).

Table 2 demonstrates that EPOC, OC, $\dot{V}O_{2end}$, and HR_{end} generally increase as the intensity of CWR increases. Although both EPOC and EPOC/OC demonstrated an increasing trend with intensity, EPOC/OC exhibited better discrimination and separation among the three intensities of LC, MC, and HC. EPOC/OC significantly increased with increasing intensity of CWR (LC vs. MC vs. HC = 27.3 ± 8.5 vs. 34.1 ± 8.4 vs. 40.6 ± 9.2%). The same trend was observed for BLa.

The BMR was inversely correlated with the EPOC/OC in all three CWR settings ($r = -0.449$, $p = 0.003$ for LC; $r = -0.590$, $p = 0.002$ for MC; and $r = -0.558$, $p < 0.001$ for HC) (Fig. 2A, B, C). Table 3 presents the results of the linear stepwise regression. In the LC, MC, and HC groups, the BMR was the major parameter associated with EPOC/OC.

As shown in Fig. 3A, B, C, BMR was positively correlated with $\dot{V}O_{2max}$, the maximal work rate, and the

Table 1 Basic information

Variables	unit	value	LC	MC	HC
sex	male/female	31/23	26/18	13/13	22/17
Age	year	33.2 ± 8.1	32.6 ± 6.9	31.4 ± 9.5	31.8 ± 6.4
body height	cm	168.0 ± 8.8	168.5 ± 8.6	167.7 ± 9.3	167.4 ± 8.5
body weight	kg	67.5 ± 13.4	68.1 ± 13.9	67.2 ± 12.6	67.1 ± 14.0
BMI	kg/m2	23.7 ± 3.1	23.9 ± 3.4	23.7 ± 3.0	23.7 ± 3.4
BMR	kcal/day/kg	27.8 ± 5.6	27.9 ± 5.6	26.8 ± 5.6	26.6 ± 4.6
INC					
$\dot{V}O_{2max}$	ml/min/kg	32.5 ± 9.9	31.4 ± 9.3	32.9 ± 9.6	31.4 ± 9.6
$\dot{V}O_{2max}$	ml/min	2193 ± 796	1226 ± 723	2192 ± 793	2106 ± 781
HR_{max}	1/min	165 ± 17	165 ± 18	161 ± 19	162.4 ± 18
WR_{max}	watt	167 ± 68	165 ± 69	179 ± 78	157 ± 64
$\dot{V}O_{2AT}$	ml/min/kg	20.2 ± 8.9	19.4 ± 8.7	21.0 ± 9.1	19.3 ± 7.6
$\dot{V}O_{2AT}$	ml/min	1377 ± 675	1333 ± 646	1437 ± 719	1310 ± 600

mean ± standard deviation

AT anaerobic threshold, *HR* heart rate, *INC* incremental exercise test, *WR* work rate, $\dot{V}O_2$ oxygen consumption

Table 2 Constant work rate exercise testing

Variables	unit	LC (N = 44)	MC (N = 26)	HC (N = 39)
EPOC	ml/kg	14.19 ± 3.78	23.72 ± 6.97*	26.49 ± 6.62#
OC	ml/kg	54.57 ± 16.16	68.43 ± 19.67*	67.76 ± 21.79#
EPOC/OC	%	27.3 ± 8.5	34.1 ± 8.4*	40.6 ± 9.2#&
BLa	mmol/liter	3.3 ± 1.5	5.6 ± 2.0*	9.9 ± 3.5#&
$\dot{V}O_{2end}$	ml/min/kg	15.21 ± 3.12	23.06 ± 6.03*	25.29 ± 6.52#
HR_{end}	/min	121 ± 12	148 ± 24*	163 ± 19#&

mean ± standard deviation

EPOC excess postoxygen consumption, *HRend* HR at the end of CWR testing, *BLa* blood lactate concentration, *OC* oxygen consumption during exercise, $\dot{V}O_{2end}$ $\dot{V}O_2$ at the end of CWR testing, *WR* work rate

LC: low-intensity constant exercise test at 35% maximal work rate 15’

MC: moderate-intensity constant exercise test at 60% maximal work rate 10’

HC: high-intensity constant exercise test at 90% maximal work rate 4’

* LC vs. MC, $p < 0.05$; #LC vs. HC, $p < 0.05$; &MC vs. HC, $p < 0.05$; one-way ANOVA with the Bonferroni post hoc test

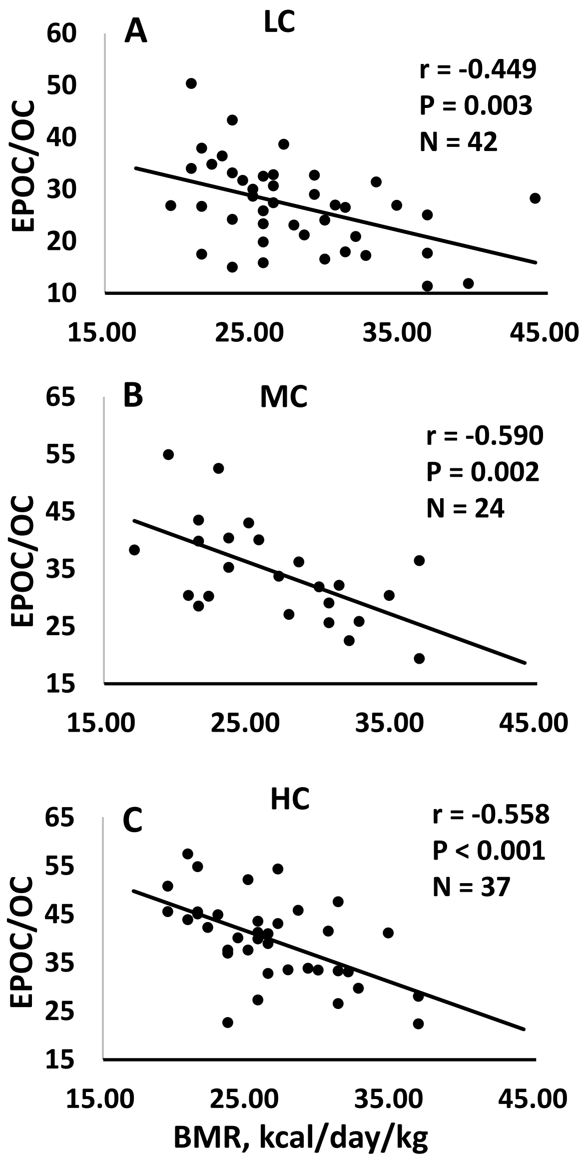

Fig. 2 Scatterplots depict the relationships between BMR and EPOC/OC at LC (low constant), MC (moderate constant) and HC (high constant) CWR tests

anaerobic threshold, as obtained in the INC. Furthermore, BMR was also negatively correlated with BLa at the end of the CWR under the LC and exhibited a marginally significant correlation with BLa under the MC and HC (Fig. 3D, E, F), similar to its relationship with EPOC/OC (Fig. 2).

Figure 4 illustrates the positive correlation between BLa and both EPOC and EPOC/OC ($r = 0.494$ and 0.546, respectively; $p < 0.001$), considering the data pooled from the three CWR intensities.

Supplementary Information shows the Pearson correlations between EPOC, EPOC/OC, BLa, and all the other variables analyzed under the conditions of LC, MC, and HC. In inter-individual comparisons, EPOC/OC correlated with BMR in all LC, MC, and HC settings; conversely, EPOC did not.

Table 3 Linear regression on predictors of EPOC/OC in LCs, MCs and HCs

Models	N	Regression coefficient (95% CI)	Standard coefficient	*P* value
Model 1: **LC**	42			
BMR		−0.669 (−1.095, −0.244)	−0.449	0.003
Model 2: **MC**	24			
BMR		−0.920 (−1.471, −0.361)	−0.590	0.002
Model 3: **HC**	37			
BMR		−1.055 (−1.594, −0.517)	−0.558	< 0.001

BMR basal metabolic rate

[*] $p < 0.05$; the p value indicates the overall significance of the linear regression model

Discussion

Main experimental findings

In accordance with our hypothesis, the present study revealed that BMR is moderately inversely correlated with EPOC/OC across different intensities of CWR and is the most important predictor of EPOC/OC when compared with BLa, age, BMI, and various parameters derived from INC and CWR CPET. Moreover, EPOC/OC demonstrated superior discrimination and separation compared with EPOC at the LC, MC, and HC intensities. Based on our literature search, this is the first study to explore the relationship between BMR and EPOC. Furthermore, the EPOC/OC parameter, along with CWR exercise testing of identical duration and relative intensity, is an applicable approach for interindividual comparisons. This parameter represents EPOC production relative to OC and may be regarded as a composite measure of aerobic energy production capacity and EPOC clearance efficiency. A higher EPOC/OC ratio could suggest a lower capacity for aerobic energy production and/or a slower rate of EPOC clearance, which might explain the stronger correlation between EPOC/OC and BMR compared to the correlation between EPOC and BMR.

Exercise forms and EPOC-related parameters

Several types of exercise forms exist for measuring EPOC, including supramaximal, submaximal, and HIIT, with either identical absolute or relative intensities, as well as all-out efforts. Although an all-out design appears straightforward, its participant-dependent nature makes it less comparable between individuals and studies [8]. In addition, it is tricky that a uniform absolute VO_2 may

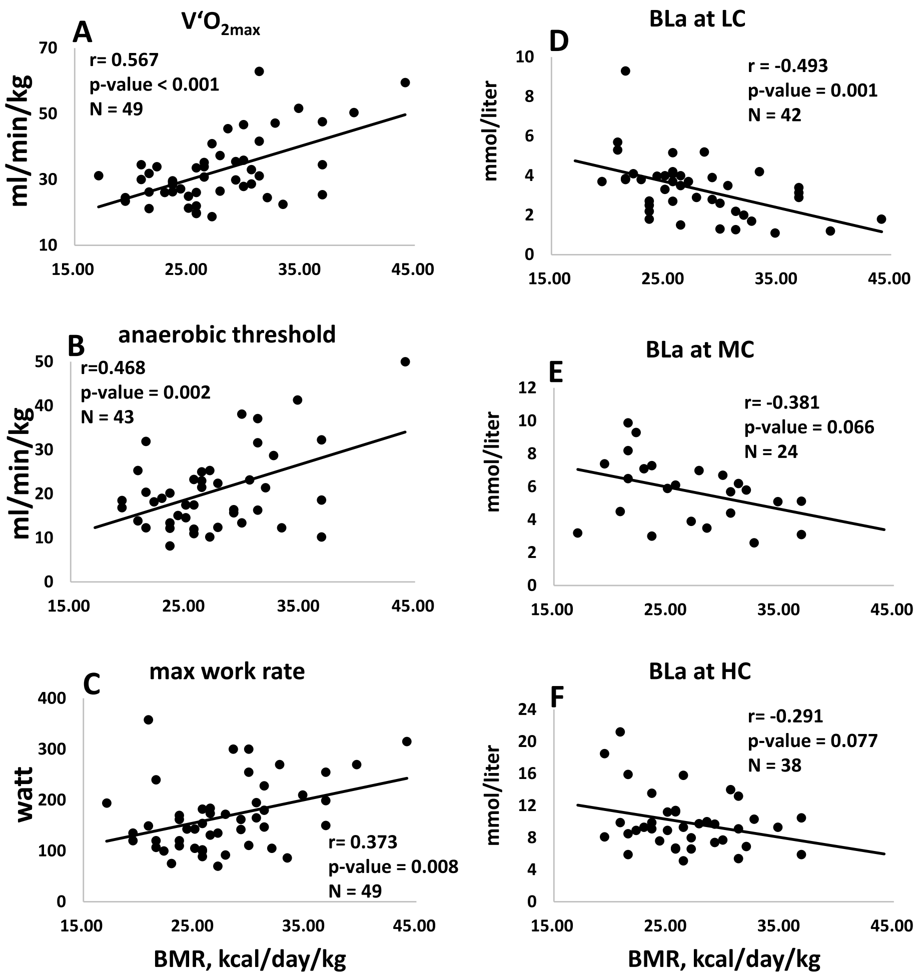

Fig. 3 Scatterplots illustrate the relationships between the BMR and $\dot{V}O_{2max}$, maximal work rate, anaerobic threshold, and BLa at the end of the LC, MC, and HC CWR tests

represent different exercise intensities in individuals with varying aerobic capacities. This discrepancy can make interindividual comparisons of the EPOC challenging. Experimental designs of CWRs with identical relative intensities appear to be more suitable for interindividual comparisons [11, 25].

Another important aspect to consider is the parameters derived from EPOC and their physiological significance. Sedlock et al. investigated the impact of long-term aerobic training on the quantity of EPOC, normalizing it to total body mass and fat-free mass (FFM) to mitigate the confounding factors of body size [11]. Simmons et al. observed greater EPOC in men than in women. However, when normalized to lean body mass, no significant difference was found, suggesting the comparability of EPOC per lean mass between the sexes [26]. In addition, Tahara et al. established a positive correlation between EPOC and FFM through the use of multiple variables, including EPOC per resting metabolic rate or $\dot{V}O_{2max}$ [14]. This indirectly supported our hypothesis that EPOC is related to BMR. Interestingly, Matsuo et al. reported a negative correlation between the maximal $\dot{V}O_2$ and the amount of EPOC produced per oxygen consumption during different exercise protocols [15]. Despite the small sample size, these findings suggest that the EPOC per oxygen consumption during exercise is closely linked to aerobic capacity. Given the need for interindividual comparisons, the present study employed the EPOC/OC parameter alongside a CWR of identical duration and relative intensity. This rarely used approach demonstrates superior discrimination among different intensities compared to EPOC and facilitates interindividual comparisons of physical traits, showing potential for future studies in EPOC.

BMR and EPOC

The BMR is a measure of resting metabolism, whereas the EPOC reflects the increase in metabolic rate

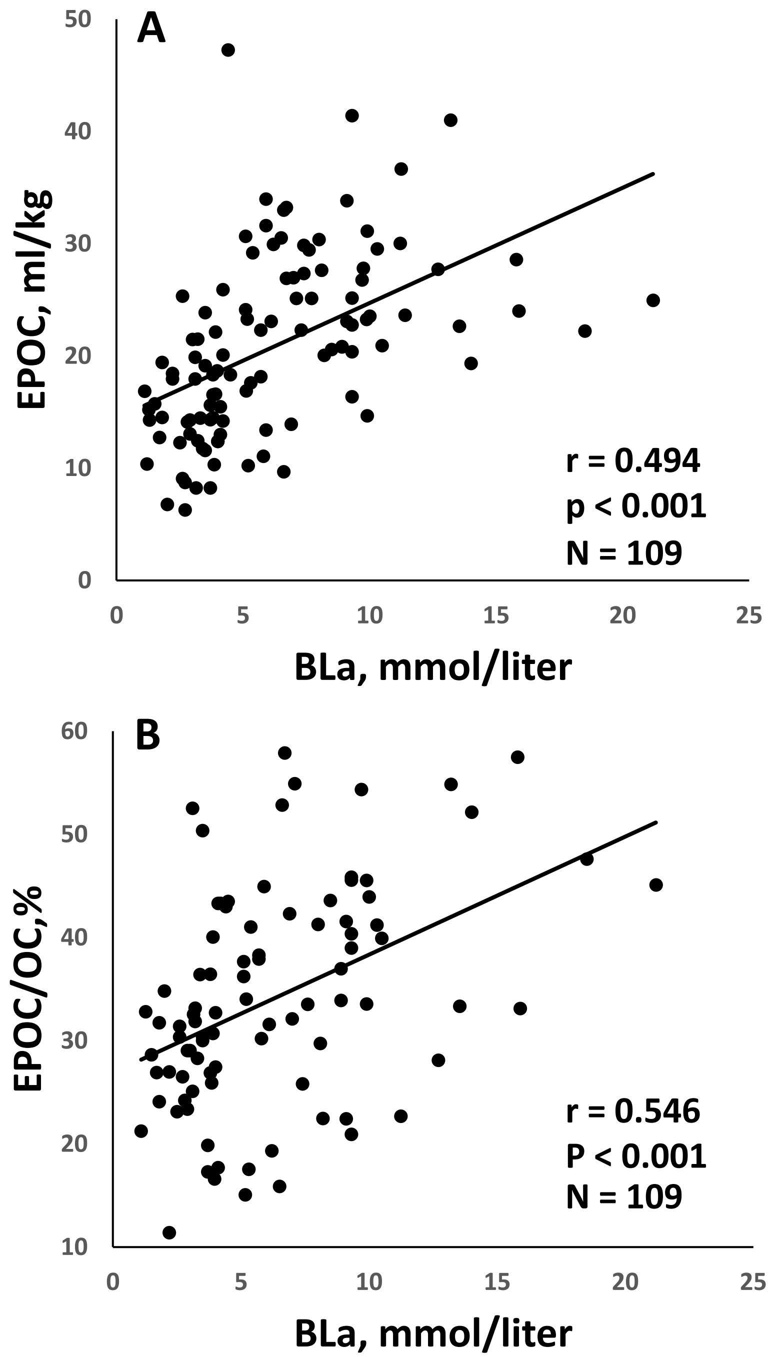

Fig. 4 Scatterplots demonstrate the relationships between BLa and EPOC and between BLa and EPOC/OC

after exercise. They serve different purposes but collectively contribute to the overall energy balance and metabolism of an individual and are linked in at least three ways. First, they can be manipulated through exercise training. The long-term effects of aerobic and resistance training generally include increases in BMR, mostly attributed to increases in lean muscle mass [9, 10]. On the other hand, Short et al. reported that trained and untrained individuals exhibited comparable magnitudes of EPOC after CWR under the same relative intensity and duration (70% VO_{2max} and 30 min) [11]. Sedlock et al. found that the magnitude of EPOC remained unchanged after aerobic training when assessed at the same relative intensity of 70%

$\dot{V}O_{2max}$ following 30 min of treadmill running. However, there was a significant decrease in the EPOC when assessed at the same absolute exercise intensity [25].

Second, they are related to similar physical traits, such as aerobic capacity. A cross-sectional study of 271 subjects revealed that participants with a higher resting metabolic rate had a significantly greater $\dot{V}O_{2max}$ [13]. In Matsuo et al.'s study, 10 participants were included, among whom a significant or nearly significant linear negative correlation was found between $\dot{V}O_{2max}$ and the ratio of EPOC to OC for three types of exercise (sprint interval, high-intensity interval aerobic exercise, and continuous aerobic exercise) [15].

Third, they are related to body composition. A previous study revealed a significant correlation between BMR and lean body mass in 81 elite Japanese male athletes [12, 13]. Alternatively, a cross-sectional study showed that the EPOC obtained after an all-out 30 s Wingate test was positively associated with body fat percentage and FFM in 14 professional cyclists [8]. Similarly, EPOC measured in 250 Japanese male athletes after short-duration exhaustive exercise revealed that those with higher FFM exhibited greater EPOC [14]. These studies have shown that both body composition and body mass affect the BMR and EPOC.

The BMR has also been shown to serve as a surrogate marker for energy availability [27–29]. This is particularly important for athletes, who are more susceptible to relative energy deficiency syndrome (RED-S). The RED-S is defined as impaired physiological functions resulting from a relative energy deficiency [30, 31]. Such deficiencies negatively impact exercise performance. A reduction in BMR has been observed in individuals with RED-S [32], likely leading to increased EPOC/OC, which can impair exercise performance. Our study also revealed a positive association between BMR and $\dot{V}O_{2max}$ and AT, as well as a negative association with BLa in CWR testing, all of which are linked to declines in exercise performance.

The present study confirmed that the BMR was moderately correlated with the EPOC/OC across low, moderate, and high CWR intensities. Furthermore, it emerged as the most significant predictor of EPOC/OC compared to BLa, age, BMI, and various parameters derived from both INC and CWR CPET. Moreover, BMR was negatively correlated with BLa at the end of the CWR under LC and exhibited a marginally significant correlation with BLa under MC and HC, similar to its relationship with EPOC/OC. In summary, our study contributes a novel perspective to the literature by refining the relationships among BMR, EPOC, OC, BLa and exercise intensity.

Blood lactate level and EPOC

The current study demonstrated a moderate positive correlation between BLa at the end of the CWR and both EPOC/OC and EPOC when analyzing data aggregated from three intensities (low, moderate, and high) of the CWR. We found two studies with findings similar to those of the current study. BAHR et al. demonstrated a high degree of linear correlation between one-hour EPOC and the BLa following supramaximal intermittent exercise [33]. Nummela's study showed that BLa correlated modestly positively with 15-min EPOC after short-term exhaustive running in athletes. Both studies employed supra-maximal exercise [24]. The present study further revealed that the correlation between EPOC and BLa persisted at submaximal exercise intensities, suggesting the significant involvement of lactate metabolism in inducing EPOC at both submaximal and maximal intensities of exercise [34].

Limitation

Owing to the inconvenience of making five hospital visits, some participants did not complete all three CWR tests, resulting in an uneven distribution among the LC, MC, and HC groups. However, the post-study statistical power for multiple regression analysis showed values of 85%, 90%, and 97% for the relationships between BMR and EPOC/OC at LC, MC, and HC, respectively, indicating that the number of participants was sufficient for data interpretation.

Conclusion

The relationship between the BMR and EPOC/OC demonstrated a moderate degree of linear negative correlation across the various CWR intensities. It emerges as the most significant predictor of EPOC/OC compared to age, BMI, resting HR, HR_{max}, $\dot{V}O_{2max}$, anaerobic threshold derived from INC, and BLa, $\dot{V}O_{2end}$, HR_{end} obtained from CWR CPET. EPOC/OC in CWR exercise testing under identical relative intensity represents EPOC production relative to OC and may be regarded as a composite measure of aerobic energy production capacity and EPOC clearance efficiency. This study not only enhances the understanding of the physiological connection between BMR and EPOC, but also introduces a practical approach for interindividual comparisons in future EPOC research.

Abbreviations

BMR	Basal metabolic rate
BLa	Blood lactate levels
$\dot{V}CO_2$	Carbon dioxide production
CWR	Constant work rate
EPOC	Excess postexercise oxygen consumption
FFM	Fat-free mass
IC	Indirect calorimetry
INC	Incremental exercise test
OC	Oxygen consumption during exercise

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13102-024-01045-7.

Additional file 1: Pearson's correlation table: excess postexercise oxygen consumption/oxygen consumption during exercise (EPOC/OC), EPOC, and blood lactate concentration (BLa) at the LC (low), MC (moderate), and HC (high constant) constant work rate tests versus parameters derived from cardiopulmonary exercise testing at incremental and corresponding CWR tests, as well as anthropometric variables.

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Not applicable

Authors' contributions
Conceptualization: Shu-Chun Huang, Kuan-Hung Chen, Chen-Hung Lee Data curation: Shu-Chun Huang, Chen-Hung Lee Formal analysis: Shu-Chun Huang, Lan-Yan Yang, Kuan-Hung Chen Funding acquisition: Shu-Chun Huang, Chen-Hung Lee Investigation: Shu-Chun Huang, Kuan-Hung Chen Methodology: Shu-Chun Huang, Lan-Yan Yang, Kuan-Hung Chen Project administration: Shu-Chun Huang, Kuan-Hung Chen Software: Lan-Yan Yang, Ching-Chung Hsiao, Kuan-Hung Chen Supervision: Lan-Yan Yang, Ching-Chung Hsiao Visualization: Shu-Chun Huang, Watson Hua-Sheng Tseng, Lan-Yan Yang, Yi-Chung Fang Writing—original draft:Shu-Chun Huang, Watson Hua-Sheng Tseng, Yi-Chung Fang, Kuan-Hung Chen Writing—review and editing: Shu-Chun Huang, Watson Hua-Sheng Tseng.

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Data availability
The data underlying the results presented in the study are available at https://docs.google.com/spreadsheets/d/12xoqDR30J-0tKvlqxxqa2YZUDJRshkmR/edit?usp=sharing&ouid=109,010,836,445,692,748,030&rtpof=true&sd=true.

Declarations

Ethics approval and consent to participate
The Institutional Review Board of Chang Gung Memorial Hospital approved the experimental protocol (Approval No. 102–2960B). All participants provided written informed consent after receiving oral and printed explanations of the experimental procedures. The study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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