Different Adaptation Patterns To Aerobic Training Despite Similar Performance Improvements

Youngsuk Seo[1], Dea Taek Lee[2], Chung, Hae Ryong[3], Ellen Glickman[4]

[1]Shinhan University, Uijeongbu, Republic of Korea, [2]Kookmin University, Seoul, Republic of Korea, [3]Clayton State University, Morrow, GA. [4]Kent State University, Kent, OH. (Sponsor: Ellen Glickman, Ph.D., FACSM)

yseokss@shinhan.ac.kr, hchung@clayton.edu

Introduction

Endurance training facilitates exercise performance through a complex integration of central and peripheral adaptations, such as enhanced oxygen delivery, mitochondrial biogenesis, and increased fatigue resistance. While markers like maximal oxygen uptake (VO_2max) and ventilatory threshold (VT1) are standardly employed to quantify these gains, significant inter-individual variability - often termed "non-response"- challenges the universality of these adaptations. This heterogeneity is frequently confounded by measurement error or insufficient training stimuli, necessitating a more rigorous approach to distinguish true physiological change from statistical artifacts. Notably, because VT1 reflects the onset of bicarbonate buffering and lactate appearance, it remains a cornerstone of exercise prescription; however, evidence suggests that functional performance may improve independently of detectable shifts in submaximal metabolic efficiency. Despite observed dissociations between aerobic capacity and metabolic thresholds, research incorporating measurement error–based frameworks to evaluate the multidimensional nature of endurance adaptivity remains sparse.

Purpose

To examine inter-individual variability in ventilatory threshold 1 (VT1) adaptation following 8 weeks of aerobic training and to determine whether baseline physiological characteristics predict training responsiveness. In addition, we evaluated whether improvements in functional performance occur independently of VT1 adaptation.

Methods

Procedures & Design

- 8-week supervised aerobic intervention (Pre-Post).
- Fat mass and FFM via BIA (InBody 570).
- Graded Exercise Test (GXT): Bruce Protocol (Cosmed K5).
- VO_2max, Time to Exhaustion (TTE), and submaximal VO_2/EE.
- Assessments at Week 0 (Baseline), Week 4 (Mid), and Week 8 (Post).

VT1 & Responder Classification

- VT1 Criteria: First non-linear increase in VE/VO_2 without VE/VCO_2 increase.
- Classification: Based on Minimal Detectable Change (MDC).
  $MDC = 1.96 \times \sqrt{2} \times SEM$
- Groups: Responders (R) vs. Non-Responders (NR) (based on MDC threshold).

Training Program

- Frequency: 2 sessions/week for 8 weeks (Supervised).
- Intensity: Heart Rate Reserve (HRR) based.
- Wks 1–5: 30–60% HRR (Progressive).
- Wks 6–8: >60% HRR (Maintenance).
- Compliance: ≥85% attendance required.

Statistical Analysis

- Binary Logistic Regression (Baseline VT1, Age, BMI).
- ROC Analysis (AUC) and Nagelkerke R^2.
- Repeated-measures ANOVA and Linear Mixed-effects Models.
- Significance: Mean ± SD; $p < 0.05$.

Baseline Predictors and VT1 Responsiveness

Table 1. Physical Characteristics of Participants

Variables	Total (n=24)	Non-Responders (n=10)	Responders (n=14)	p
Age (years)	24.5 ± 2.8	24.8 ± 4.3	25.2 ± 1.5	0.884
BMI (kg/m²)	24.1 ± 2.0	24.0 ± 2.2	24.1 ± 1.9	0.812
VO_2max (ml/kg/min)	52.0 ± 6.8	52.6 ± 5.7	53.3 ± 7.4	0.790
Body Fat (%)	18.1 ± 5.9	17.2 ± 4.7	18.1 ± 7.2	0.695

Values are expressed as Mean ± Standard Deviation (SD)

No significant differences were observed in baseline VO_2max between groups ($p = 0.79$).

Table 2. Logistic regression predicting VT1 responsiveness

Predictor	β	SE	OR	95% CI	p
BMI (kg/m²)	−0.168	0.265	0.845	0.481-1.442	0.525
Age (years)	−0.114	0.180	0.892	0.608-1.287	0.526
Pre_VT1 (ml/kg/min)	−0.339	0.163	0.712	0.471-0.919	0.037*

Data are presented as mean ± standard deviation (SD). BMI, body mass index; Pre_VT1, baseline ventilatory threshold 1; OR, odds ratio; CI, confidence interval. *p ≤ 0.05

Binary logistic regression confirmed that baseline VT1 is a significant negative predictor of responsiveness (β = -0.339, OR = 0.712, $p = 0.037$).

Receiver Operating Characteristic (ROC) Analysis

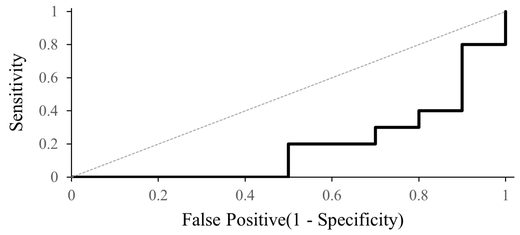


Figure 1. Receiver operating characteristic (ROC) curve illustrating the predictive ability of baseline VT1 for training responsiveness.

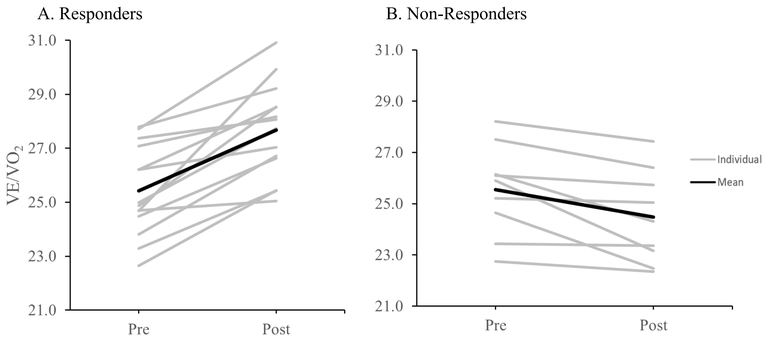


Figure 2. Individual changes in ventilatory threshold 1 (VT1) from pre- to post-intervention in (A) responders and (B) non-responders. Data are presented as mean ± standard deviation (SD).

Exercise Duration as a Measure of Functional Performance

Table 3. Exercise duration and maximal oxygen uptake

	Exercise duration(sec)		VO_2max (ml/kg/min)	
	NR	R	NR	R
Pre	792.3 ± 67.9	768.7 ± 60.0	52.6±5.7	53.3±7.4
Post	847.1 ± 59.8	821.4 ± 54.5	50.1±6.5	54.6±6.8
Change (Δ)	+54.8	+52.7	-2.5	+1.3

NR, non-responder; R, responder. Data are presented as mean ± standard deviation (SD)

A repeated-measures ANOVA confirmed a highly significant main effect of time ($p < 0.001$), with a large effect size ($\eta p^2 = 0.722$). This indicates that the training program was robustly effective in improving exercise tolerance across all participants.

Submaximal Metabolic Responses

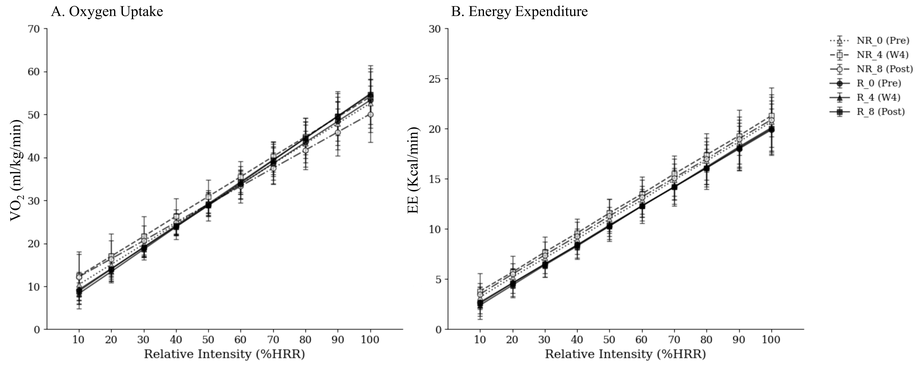


Figure 3. Submaximal metabolic responses across relative intensity levels (A) Oxygen uptake (VO_2, No significant effects of Group ($p = 0.163$), Time ($p = 0.479$), or Interaction ($p = 0.606$)) and (B) energy expenditure (EE, No significant effects of Group ($p = 0.072$), Time ($p = 0.665$), or Interaction ($p = 0.744$)).

Conclusion

Eight weeks of aerobic training improved exercise tolerance independent of changes in submaximal metabolic economy or ventilatory threshold shifts. Initial VT1 predicts magnitude of subsequent VT1 adaptation, consistent with a physiological ceiling effect; however, functional adaptations occurred regardless of threshold classification. These findings highlight the multidimensional nature of endurance adaptation and caution against defining training success solely by changes in ventilatory thresholds.