# UTILIZING LACTATE THRESHOLD TO INVESTIGATE THE EFFECT OF HEAT ON LUNG DIFFUSING CAPACITY DURING EXERCISE

**K.A. Lee**, C.I. Nicol, K.E. Coffman
University of Puget Sound

Est. 1888 UNIVERSITY of PUGET SOUND | Exercise Science

## Introduction

- Combined heat and exercise have been shown to alter the cardiovascular system's hemodynamic responses, which is determined by factors such as the magnitude of the environmental (heat or cold) load, duration, intensity, and type of exercise (Gonzalez-Alonso, 2012, Chou et al. 2023, Rowell, 1974).
- Lung diffusing capacity for carbon monoxide (DLCO) has been used to objectively assess the efficiency of gas exchange in the human respiratory system. This parameter quantifies the capacity of the lungs to facilitate the transfer of gases from the alveoli into the pulmonary capillary blood (Blakemore et al. 1957).
- Previous work showed that DLCO is higher in the heat during exercise at 40%, but not 20%, of maximum workload ($W_{max}$) (Schoeberlein, 2023).

## Aims and Hypotheses

- **AIMS**: To extend previous work by 1) using a lower heat stress to allow for completion of higher workloads and 2) prescribing workloads as a function of lactate threshold (LT), in addition to $W_{max}$, to better control for subjects of varying aerobic fitness.
- **HYPOTHESES**: We hypothesize that 1) This protocol will allow for investigation of DLCO in heat versus thermoneutral conditions at a high-intensity exercise stage; 2) At rest, DLCO will be similar in heat compared to thermoneutral conditions; and 3) DLCO will be higher in the heat versus thermoneutral conditions during moderate-high intensity exercise.

## Results

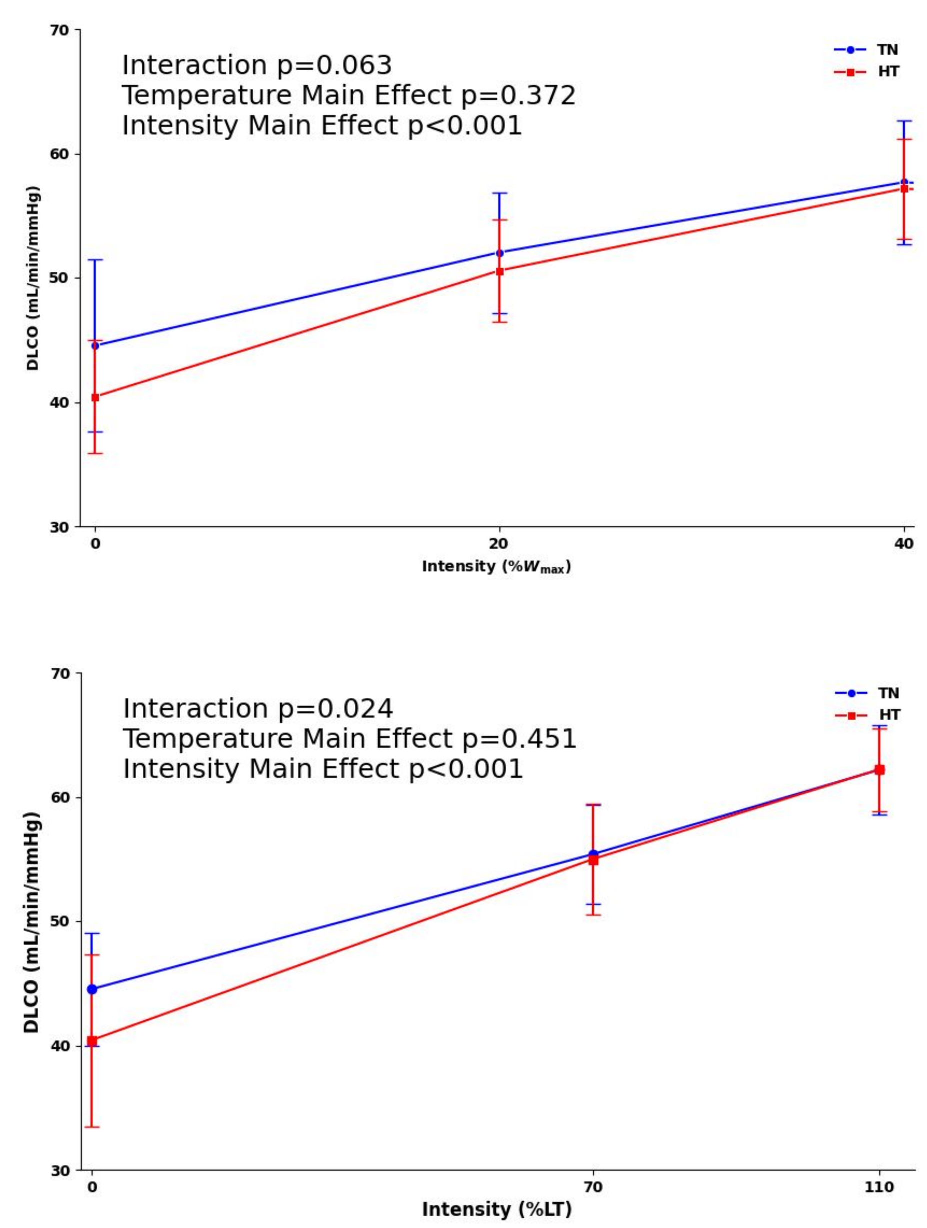



**Figure 1.** DLCO as a function of %$W_{max}$ (top) and %LT (bottom). DLCO increased with exercise intensity (both P<0.001). There was a significant interaction between temperature and intensity when assessed as a function of LT only. DLCO, lung diffusing capacity for carbon monoxide; Wmax, maximum workload; LT, lactate threshold; TN, thermoneutral; HT, heat.

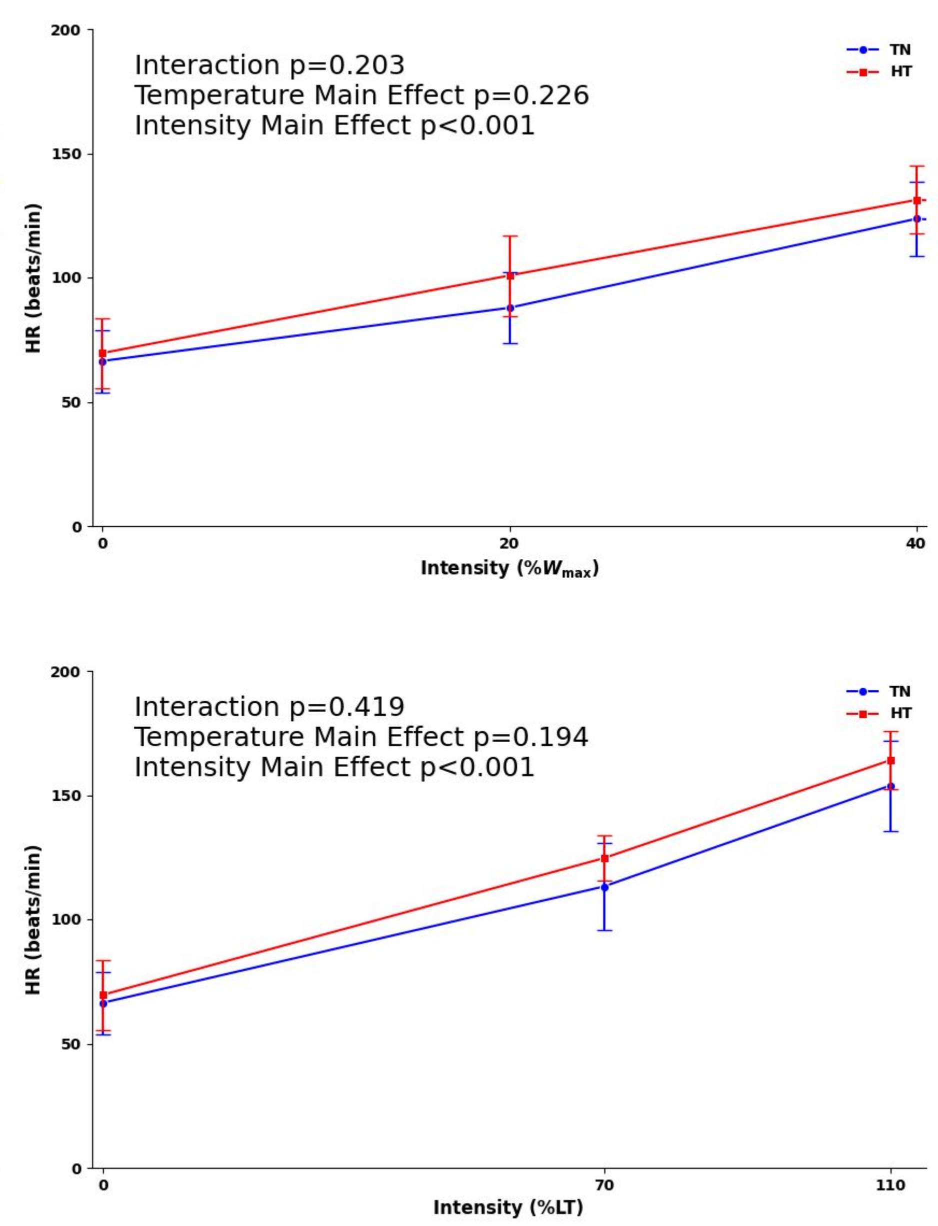



**Figure 2.** HR as a function of %$W_{max}$ (top) and %LT (bottom). HR increased with exercise intensity (both P<0.001). There was no significant interaction between temperature and intensity. HR, heart rate; Wmax, maximum workload; LT, lactate threshold; TN, thermoneutral; HT, heat.

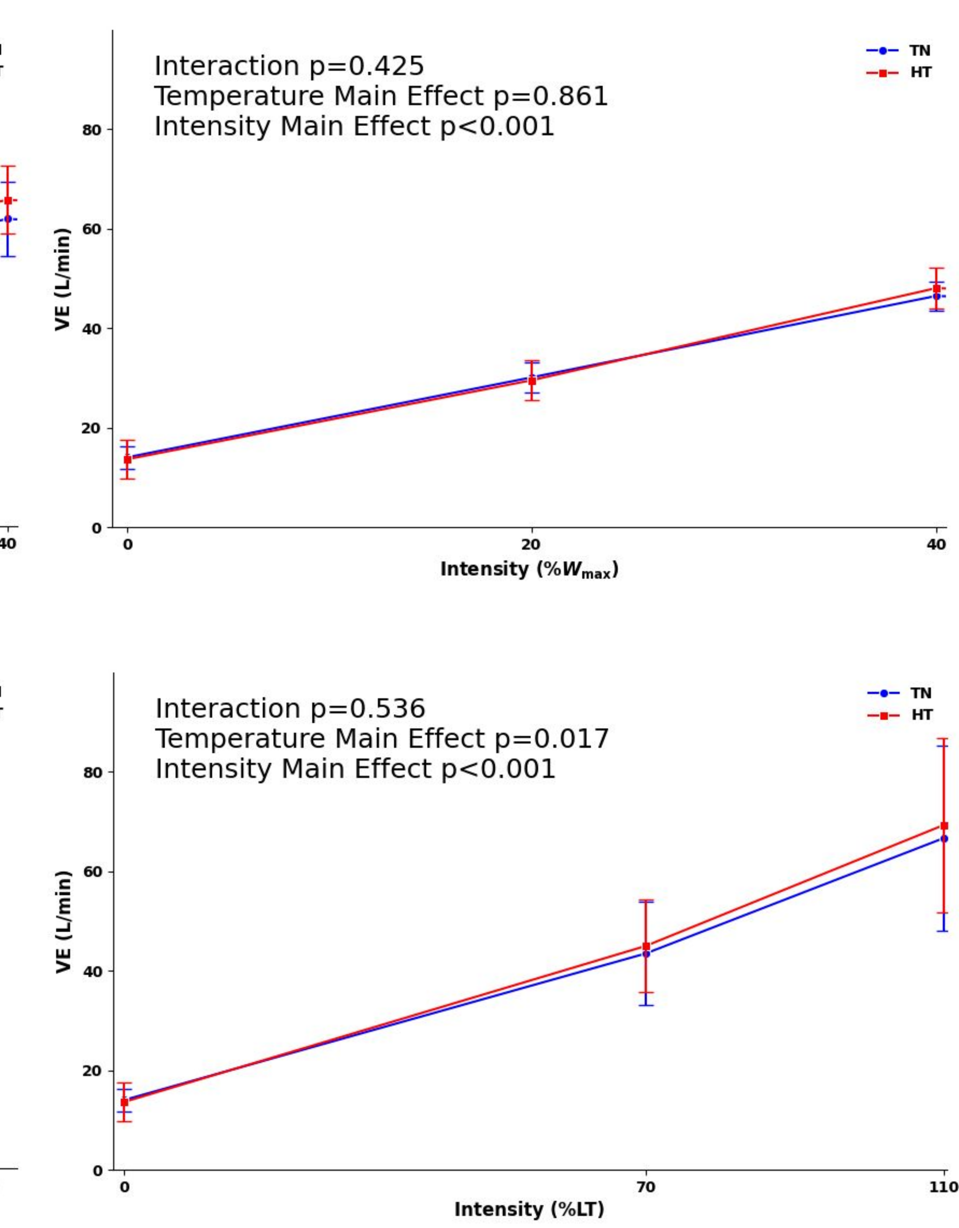



**Figure 3.** VE as a function of %$W_{max}$ (top) and %LT (bottom). VE increased significantly with exercise intensity (both P<0.001). There was no significant interaction between temperature and intensity. VE, minute ventilation; Wmax, maximum workload; LT, lactate threshold; TN, thermoneutral; HT, heat.

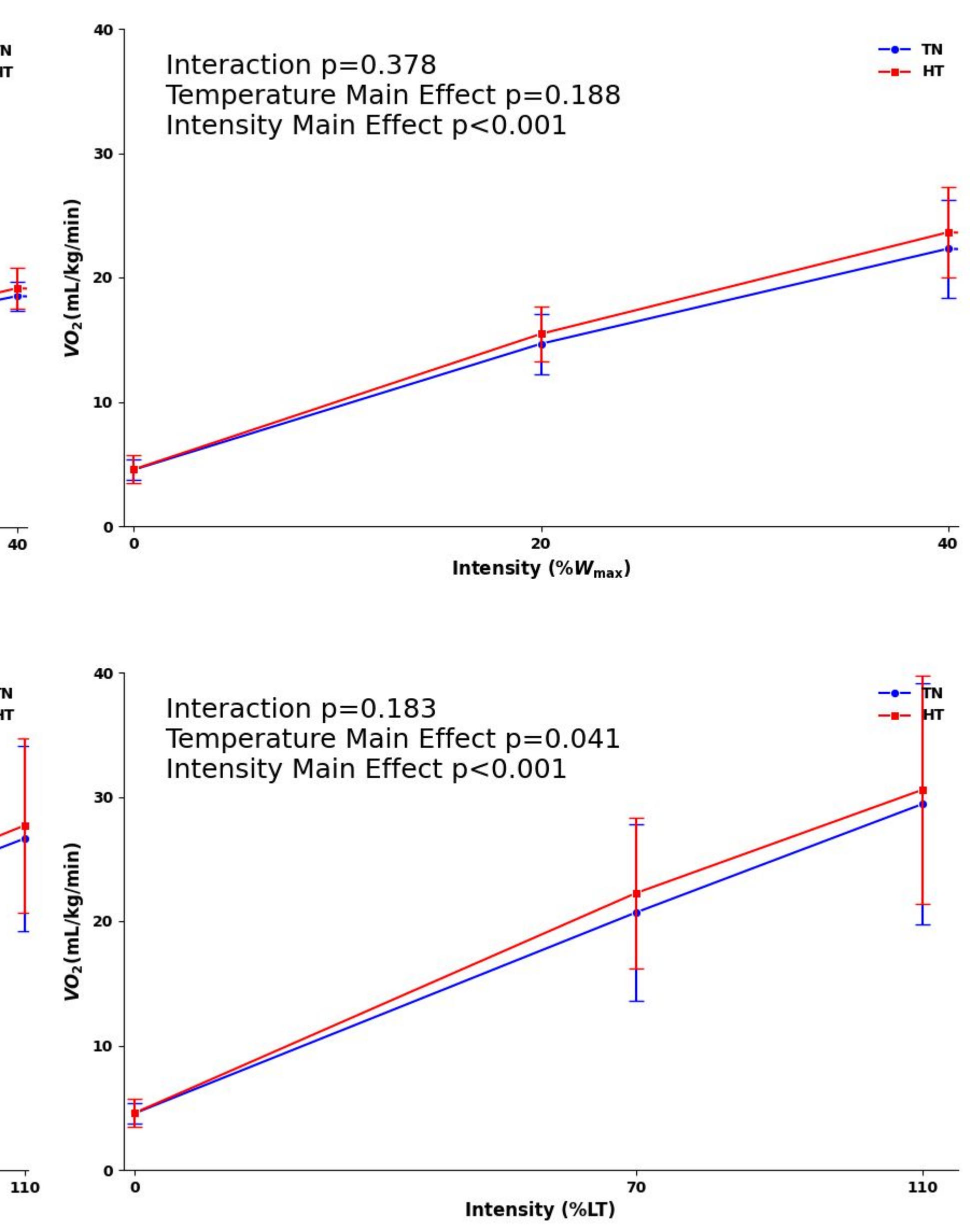
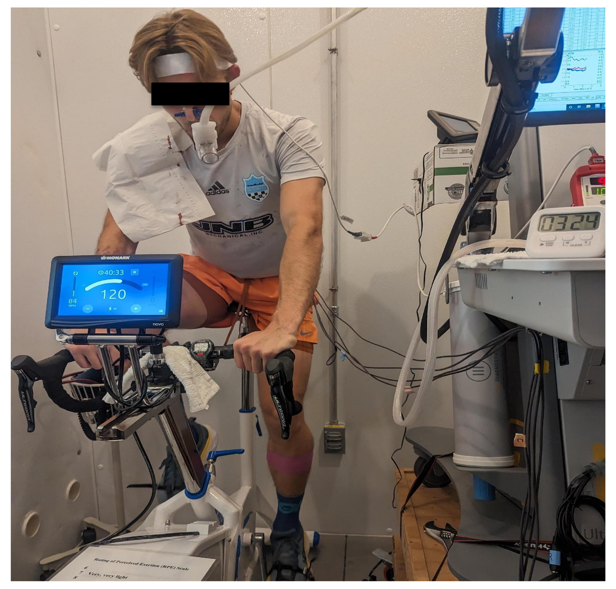


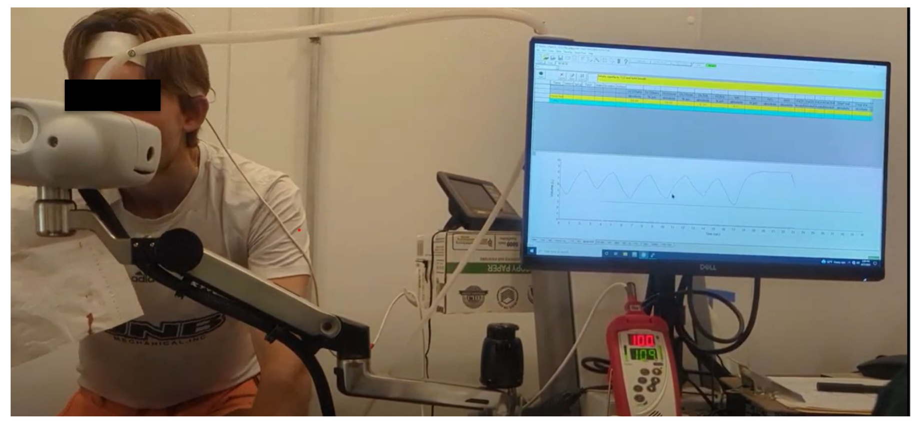

**Figure 4.** $VO_2$ as a function of %$W_{max}$ (top) and %LT (bottom). $VO_2$ increased significantly with exercise intensity (both P<0.001). There was no significant interaction between temperature and intensity. $VO_2$ was higher overall in HT vs. TN when assessed as a function of LT only. $VO_2$, oxygen consumption; Wmax, maximum workload; LT, lactate threshold; TN, thermoneutral; HT, heat.

## Methods

- Five male (Table 1) recreationally active, non-smoking adults with no history of cardiorespiratory diseases participated in 3 visits.
- Visit 1: Incremental exercise test to determine cycling $W_{max}$ and LT, quantified using the Log-Log method in the R package lactater.
- Visits 2 and 3: Cycling at rest, 20 and 40% $W_{max}$, and 70 and 110% LT in a hot (HT; 35ºC) or thermoneutral (TN; 20ºC) chamber.
- Parameters measured during exercise included DLCO, heart rate (HR), minute ventilation ($V_E$), and oxygen consumption ($VO_2$).
- Statistics: Two-way repeated measures ANOVA (temperature x intensity) in terms of both %$W_{max}$ (0, 20, 40) and %LT (0, 70, 110). Significance was set at P<0.05.



Chamber Set-Up: Upright cycle ergometer and metabolic cart. Subject completing ventilation and gas exchange measurements.



Subject performing DLCO maneuvers during exercise

Measuring blood pressure during exercise

**Table 1.** Characteristics of subjects.

| | | | |
|---|---|---|---|
| *Demographics* | | | |
| **N (M/F)** | 5 (5/0) | | |
| **Age (y)** | 23 | ± | 7 |
| **Height (cm)** | 184 | ± | 5 |
| **Weight (kg)** | 85.4 | ± | 7 |
| **BMI (kg/m$^2$)** | 25.3 | ± | 3.1 |
| *Lung Function* | | | |
| **FVC (L)** | 6.9 | ± | 0.5 |
| **FVC, % predicted** | 115 | ± | 11 |
| **$FEV_1$ (L)** | 5.1 | ± | 0.3 |
| **$FEV_1$, % predicted** | 103 | ± | 9 |
| *Exercise Performance* | | | |
| **Wpeak (W)** | 291 | ± | 60 |
| **W at LT (W)** | 153 | ± | 62 |
| **LT, % of Wmax** | 51 | ± | 9 |
| **$VO_2$peak (ml/kg/min)** | 50.8 | ± | 11.3 |

BMI (body mass index); FVC (forced vital capacity); $FEV_1$ (forced expiratory volume in 1 s); $W_{peak}$ (peak workload); LT (lactate threshold); $VO_2$peak (peak oxygen consumption).

## Discussion

- Conventional thought suggests that exposure to heat triggers increased cardiac output (Q). This may augment blood volume in the pulmonary vasculature, thereby enhancing lung surface area for gas exchange (Coffman et al., 2018).
- Unexpectedly, there was no effect of heat on DLCO during exercise when assessed in terms of $W_{max}$, even with the inclusion of a high-intensity workload, suggesting that the heat stress was inadequate to increase lung surface area.
- While we observed a significant interaction of temperature and intensity when analyzing DLCO as a function of LT, these findings are inconclusive as we could not statistically identify any simple main effects.
- Nevertheless, the significant interaction in DLCO when analyzed as a function of LT suggests that controlling for aerobic fitness may be important for detecting physiological effects of heat on lung diffusing capacity during exercise.

## Conclusions

- Ultimately, this research calls for a more comprehensive investigation into the complex physiological mechanisms governing pulmonary vascular hemodynamics under heat stress during physical exertion.
- Studies incorporating various levels of heat stress and subject fitness, alongside measurement of skin blood flow and sympathetic drive, are needed to better understand the impact of heat exposure on DLCO during exercise.

## References

1. Chou TH, Coyle EF (2022). Cardiovascular responses to hot skin at rest and during exercise. *Temperature (Austin)*. 10(3):326-357.
2. Coffman KE, Curry TB, Dietz NM, et al (2018). The influence of pulmonary vascular pressures on lung diffusing capacity during incremental exercise in healthy aging. *Physiol Rep.* 6:e13565.
3. González-Alonso J (2012). Human thermoregulation and the cardiovascular system. *Exp Physiol.* 97:340–346.
4. Rowell LB (1974). Human cardiovascular adjustments to exercise and thermal stress. *Phys Reviews.* 54:75-159.
5. Schoeberlein MI, Frisiras CE, Coffman KE (2023). The effect of heat on lung diffusing capacity for carbon monoxide (DLCO) during cycling exercise. *Eur J Appl Physiol*. Online ahead of print.

## Acknowledgements

Special thanks to Dr. Kirsten Coffman for her amazing mentorship throughout this research, the University of Puget Sound Exercise Science Department for their support, the University Enrichment Committee for funding, and to all of the subjects who participated.