# A Study Examining the Reliability of Identification & Validity of Ventilatory Thresholds in Relation to Human Endurance Performance

Miramani M. Lenzini[1], Elizabeth D. Hubbell[2], Keston G. Lindsay[2], Addison D. Rhodes[1], James Pearson[2], Andrew W. Subudhi[2], & Robert A. Jacobs[2]

## ABSTRACT

Ventilatory thresholds (VTs), which are identified by analyzing various changes in ventilatory gasses during exercise, relate to parameters of health and disease in humans. Thus, the applied and clinical value of VTs is high. However, there are multiple ways by which VTs can be assessed with no general consensus on the best method. This study examined the reliability of identification and validity in relation to endurance performance of the most common VTs across 60 and 43 human participants, respectively. We found that the VT identified by assessing the ventilatory equivalents of oxygen curve is the most reliable and valid VT.

## INTRODUCTION & STUDY AIM

Metabolic thresholds (also referred to as fatigue or performance thresholds) represent the intensity of physical activity at which skeletal muscle fiber-type recruitment changes and/or substrate utilization in muscle shifts, influencing time-to-fatigue. Metabolic thresholds can be assessed by collecting samples of ventilatory gasses or blood lactate during exercise and are commonly referred to as a ventilatory threshold (VT) or a lactate threshold, respectively. VTs have been identified as equivalent to or better than lactate thresholds for assessing metabolic thresholds and they do not require the collection of blood for the threshold identification. VTs have also been shown to correlate with endurance performance and all-cause mortality. Thus, VTs relate to both health & disease in humans. However, there are many different methods used to assess VTs across the literature with little understanding of which VTs are better. Accordingly, we aimed to assess the reliability of identifying different VTs and examined their validity in relation to human endurance performance.

## METHODS

Sixty study participants underwent an incremental exercise test on a cycle ergometer to volitional fatigue. Study participants characteristics are shown in the results. A collection of ventilatory gasses were obtained during all incremental exercise tests and used to determine different VTs. Endurance performance on a cycle ergometer was also assessed in a subgroup of the participants (n = 43). The VTs assessed included the gas exchange threshold (GET) considered a moderate-intensity VT and respiratory compensation point (RCP) considered a high-intensity VT along with ventilatory equivalents (VEQ) and ventilatory equivalent of oxygen ($VE/VO_2$) methods, both of which represent low, moderate, and high intensity VTs. All VT assessments were determined by the same 4 researchers with the data necessary for each VT assessment processed in 10-sec and 30-sec rolling averages along with exponential smoothing - totaling 756 VT assessments per reviewer. One reviewer was unblinded while the other 3 were blinded to the study participants and data processing method. Blinded reviews were randomized and provided in a counterbalanced order.

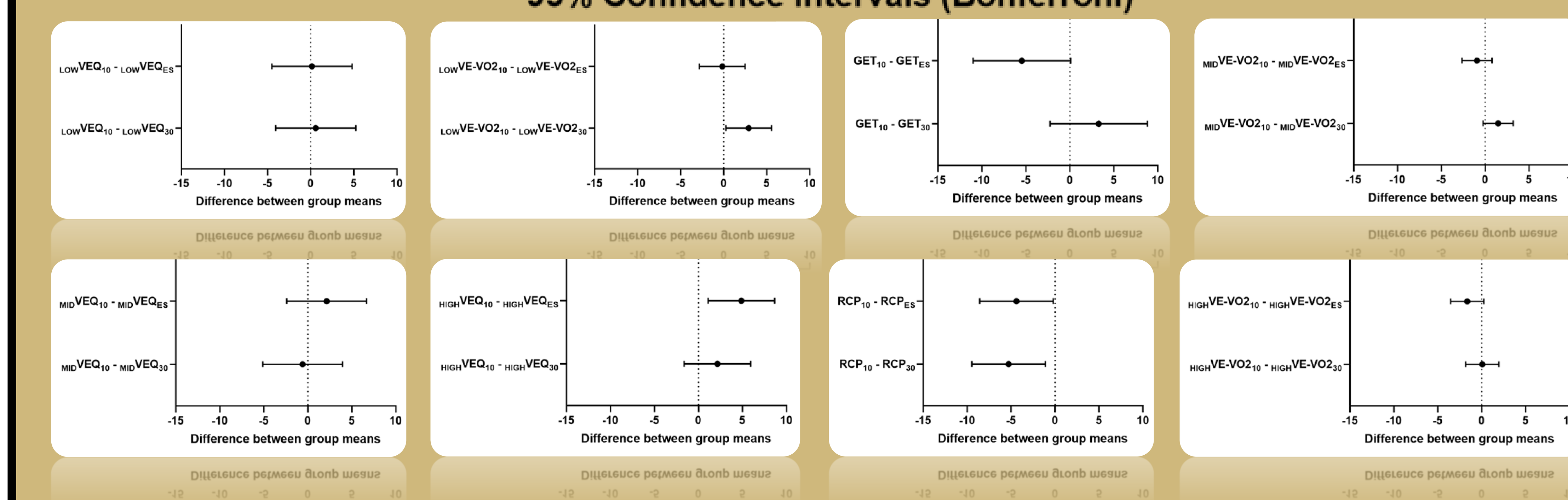
## RESULTS

| Sample Size | Age (yrs) | Height* (cm) | Weight* (kg) | BMI* | $VO_{2max}$* (ml $O_2 \cdot kg^{-1} \cdot min^{-1}$) | $W_{max}$* (Watts) |
|---|---|---|---|---|---|---|
| Female (n = 13) | 31.6 ± 14.5 | 164.5 ± 7.3 | 57.3 ± 7.4 | 21.1 ± 1.8 | 43.8 ± 7.0 | 211.3 ± 40.2 |
| Male (n = 47 ) | 32.6 ± 10.5 | 180.3 ± 5.1 | 78.8 ± 13.1 | 24.2 ± 3.7 | 49.7 ± 10.0 | 319.7 ± 71.7 |
| All (n = 60) | 32.4 ± 11.3 | 176.9 ± 8.6 | 74.1 ± 14.9 | 23.5 ± 3.6 | 48.4 ± 9.7 | 296.2 ± 78.7 |

*** represents a significant difference between female and male participants (p < 0.05)**

### Aim 1

**95% Confidence Intervals (Bonferroni)**




### Aim 2

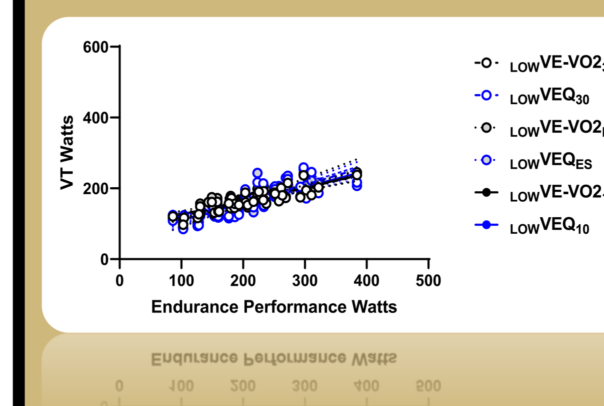
| Processing Method | GET | RCP | VEQ | $VE/VO_2$ |
|---|---|---|---|---|
| 10 sec rolling averages | N/A | N/A | 16.8 ± 8.6%[a] | 5.1 ± 5.4%[b] |
| 30 sec rolling averages | N/A | N/A | 14.6 ± 9.5%[a] | 2.9 ± 3.2%[b,c] |
| Exponential Smoothing | N/A | N/A | 15.2 ± 10.0%[a] | 2.8 ± 2.7%[c] |

| Processing Method | GET | RCP | VEQ | $VE/VO_2$ |
|---|---|---|---|---|
| 10 sec rolling averages | 12.2 ± 7.4%[a] | N/A | 10.2 ± 5.6%[a] | 2.7 ± 2.2%[b] |
| 30 sec rolling averages | 9.4 ± 5.9%[a] | N/A | 9.7 ± 4.8%[a] | 1.7 ± 1.4%[c] |
| Exponential Smoothing | 12.2 ± 6.9%[a] | N/A | 9.7 ± 5.2%[a] | 1.6 ± 1.4%[c] |

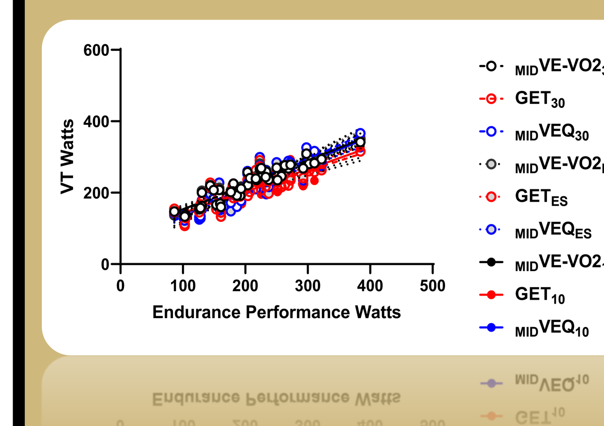
| Processing Method | GET | RCP | VEQ | $VE/VO_2$ |
|---|---|---|---|---|
| 10 sec rolling averages | N/A | 7.0 ± 4.3%[a] | 6.2 ± 3.4%[a,b] | 1.8 ± 2.2%[d] |
| 30 sec rolling averages | N/A | 4.2 ± 3.9%[c] | 6.4 ± 3.2%[a,b] | 1.4 ± 1.6%[d] |
| Exponential Smoothing | N/A | 4.9 ± 4.8%[b,c] | 6.9 ± 4.3%[a] | 1.0 ± 0.8%[d] |

**Coefficient of Variation (CV; SD/mean, %) of watts at threshold**
Thresholds with different superscripted letters represent a significant difference ($p < 0.05$)

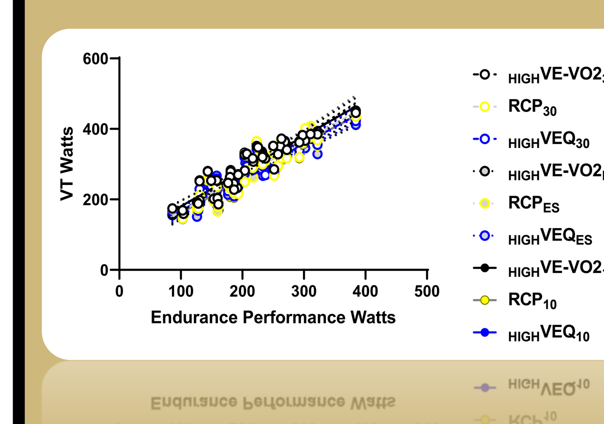
### Aim 3




| Method | $R^2$ | F; P value |
|---|---|---|
| $VEQ_{10}$ | 0.7021 | 96.6; < 0.0001 |
| $VEQ_{30}$ | 0.6839 | 88.7; < 0.0001 |
| $VEQ_{ES}$ | 0.6788 | 86.7; < 0.0001 |
| $VE/VO2_{10}$ | 0.7122 | 101.5; < 0.0001 |
| $VE/VO2_{30}$ | 0.7539 | 125.6; < 0.0001 |
| $VE/VO2_{ES}$ | 0.7100 | 100.4; < 0.0001 |




| Method | $R^2$ | F; P value |
|---|---|---|
| $GET_{10}$ | 0.7809 | 146.1; < 0.0001 |
| $GET_{30}$ | 0.7566 | 127.4; < 0.0001 |
| $GET_{ES}$ | 0.7688 | 136.3; < 0.0001 |
| $VEQ_{10}$ | 0.8422 | 218.8; < 0.0001 |
| $VEQ_{30}$ | 0.8549 | 241.5; < 0.0001 |
| $VEQ_{ES}$ | 0.7953 | 159.3; < 0.0001 |
| $VE/VO2_{10}$ | 0.8511 | 234.3; < 0.0001 |
| $VE/VO2_{30}$ | 0.8675 | 268.4; < 0.0001 |
| $VE/VO2_{ES}$ | 0.8580 | 247.7; < 0.0001 |




| Method | $R^2$ | F; P value |
|---|---|---|
| $RCP_{10}$ | 0.8271 | 196.1; < 0.0001 |
| $RCP_{30}$ | 0.8335 | 205.3; < 0.0001 |
| $RCP_{ES}$ | 0.8496 | 231.5; < 0.0001 |
| $VEQ_{10}$ | 0.8663 | 265.7; < 0.0001 |
| $VEQ_{30}$ | 0.8608 | 253.5; < 0.0001 |
| $VEQ_{ES}$ | 0.8406 | 216.1; < 0.0001 |
| $VE/VO2_{10}$ | 0.8538 | 239.5; < 0.0001 |
| $VE/VO2_{30}$ | 0.8616 | 255.3; < 0.0001 |
| $VE/VO2_{ES}$ | 0.8619 | 256.0; < 0.0001 |

## CONCLUSIONS

**The first aim of the study** was to determine if different data processing methods influence VT determination. Data processing methods included 10-sec and 30-sec rolling averages along with exponential smoothing. While different methods of data processing did influence mean VTs identified to some degree for all VTs analyzed, no method of data processing influenced the slope of the relationship between VT and endurance performance. **The second aim of the study** was to assess the reliability of VT threshold identification across 4 different reviewers. Determination of the $VE/VO_2$ threshold was shown to be significantly more reliable than all other methods. **The third aim of the study** was to report the validity of all VT methods in relation to endurance performance of which the determination of $VE/VO_2$ threshold was, again, identified as the best.

## INSTITUTIONAL AFFILIATIONS

[1]Department of Biology, University of Colorado Colorado Springs, Colorado Springs, CO, USA;
[2]Department of Human Physiology & Nutrition, University of Colorado Colorado Springs, Colorado Springs, CO, USA

University of Colorado Colorado Springs

University of Colorado
Boulder | Colorado Springs | Denver | Anschutz Medical Campus