Calculating Ventilatory Threshold in Patients After Stroke

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Abstract

BACKGROUND: Aerobic training intensity is commonly determined from heart rate reserve (HRR) or a percentage of maximal heart rate measured during a graded exercise stress test. This method has limitations in people after stroke, who may not reach maximal heart rate. Ventilatory Threshold (VT) is an alternate method of establishing aerobic training intensity. VT indicates the exercise intensity above which ventilation increases disproportionately compared to whole-body oxygen uptake, theoretically representing the optimal intensity for sustaining aerobic exercise.

METHODS: This study assessed the most effective ways of calculating VT from gas-exchange data from patients after stroke. We used retrospective analyses of gas-exchange data collected during submaximal and maximal stress tests with post-stroke individuals. Data were graphed using 3 different methods to determine if they provide similar information.

RESULTS: Mean (standard deviation) VT time was 3.355 (1.349) minutes using the Ventilation Curve method; 3.383 (1.372) minutes using the V-Slope Method; and 2.725 (1.118) minutes using the Ventilatory Equivalents method. ANOVA results indicate that the Ventilation Curve method and the V-slope methods yield equivalent VT values (p=0.83), but VT was achieved earlier using the Ventilatory Equivalents method (p=0.04).

CONCLUSION: Ventilatory Threshold in stroke patients undergoing treadmill testing can be effectively calculated from gas exchange data using the Venilation Curve and the V-slope methods. More research is needed to assess other factors that may affect VT measurements, such as medications or diseases impacting respiratory and cardiac function in patients with stroke to determine the most optimal and effective means of establishing training intensity after stroke.

Introduction

Each year 800, 000 people are affected by stroke, causing long-term disability and serious medical sequelae in a patient population with already pre-morbidly low levels of physical fitness. Low aerobic capacity is associated with mortality among healthy individuals, and also among those with cardiac comorbidities and/or a previous history of stroke.

Since stroke further reduces cardiovascular health, aerobic training after stroke is important for both overall reduction in mortality risk and reduction in risk of subsequent stroke. Heart rate reserve (HRR) or some percentage of maximal heart rate (HR_{max}) are commonly used to formulate aerobic exercise intensity. However, the sequelae that accompany stroke may impair the ability to achieve maximal heart rate. This could result in over-dosing exercise when using HRR or $\%HR_{max}$ methods, which could be frustrating or potentially dangerous for patients after stroke.

Ventilatory Threshold (VT) is closely correlated to the anaerobic threshold, the point at which the body shifts from aerobic to anaerobic metabolism.[1] Training just below the anaerobic threshold has been shown to be an effective and efficient means of increasing aerobic fitness.[2] VT could provide a more accurate means of establishing exercise intensity after stroke since it does not depend on HR response.

While VT has been used to determine aerobic exercise training intensity for patients with cardiovascular disease, there is a paucity of information with regards to its application in patients after stroke.[3] Additionally, VT has been calculated in different ways by various researchers. We were interested in whether the application of the different methods would result in similar values for VT. This is worth investigating to more accurately prescribe exercise in stroke populations.

Methods

This study analyzed data gathered from VT trials in patients with a history of chronic stroke undergoing sub-maximal and maximal exercise testing from previous studies. De-identified gas-exchange data including VO_2, VCO_2 and VE from post-stroke subjects participating in treadmill walking were used. In total, data from 39 treadmill tests involving 15 participants (12 male) at least 6 months post-stroke were analyzed.

Calculation of VT

3 methods were used to calculate VT: the Ventilation Curve, the V-Slope Method and the Ventilatory Equivalents method (Fig. 1-3). The results were tabulated in excel and a point by point comparison of the slopes of the data points was done to determine the highest rise in the pertinent parameter for each of the methods. This was then visually verified through the graphs for each method to account for variability and spurious points in the readings. Trendlines were also used to determine the inflection points as a further visual verification for the calculated VT.

Results

The average value for the time at which VT was achieved for the Ventilation Curve was 3.355 (1.349) minutes. For the V-Slope Method it was 3.383 (1.372) minutes. The Ventilatory Equivalents method averaged 2.725 (1.118) minutes, significantly lower than the other 2 methods of calculating VT.

ANOVA (Figs. 5-6) results showed that when comparing VT using the time stamps for the onset of anaerobic respiration in the gas exchange data, the

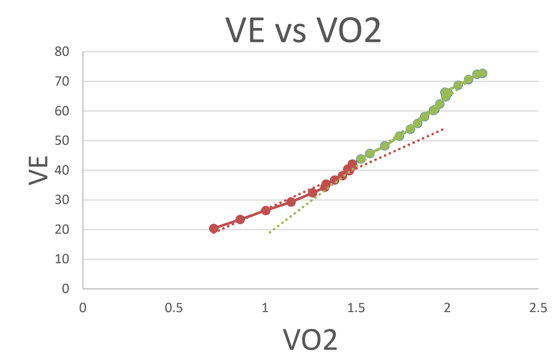


***Figure 1**: Ventilation Curve - The Ventilation curve involves plotting the minute ventilation (VE) against oxygen consumption (VO2) with the point at which linear rise in VE with regards to VO2 begins to become non-linear. This reflects the increasing ventilatory rate in compensation for rising lactate levels*

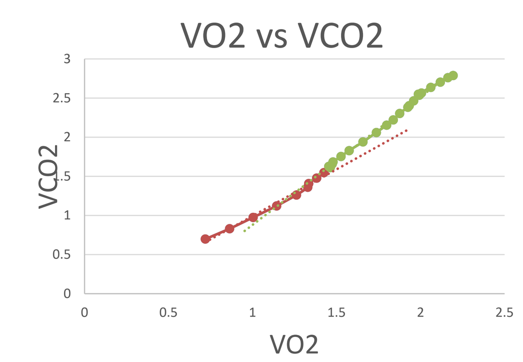


***Figure 2**: V-Slope - The V-Slope Method, first proposed by Beaver et al, requires that VO2 be plotted against CO2 consumption (VCO2). Here, the VT is determined to be at the VO2 measurement that corresponds with an increase in the slope of the VO2 to VCO2 plot.*

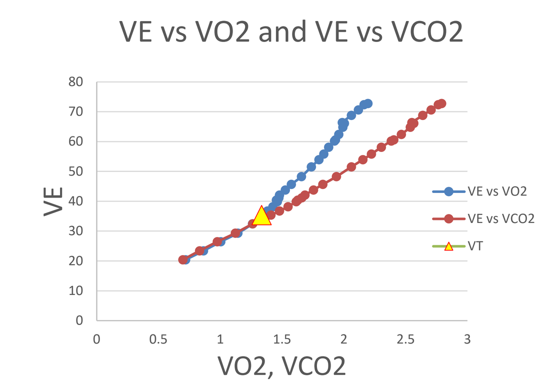
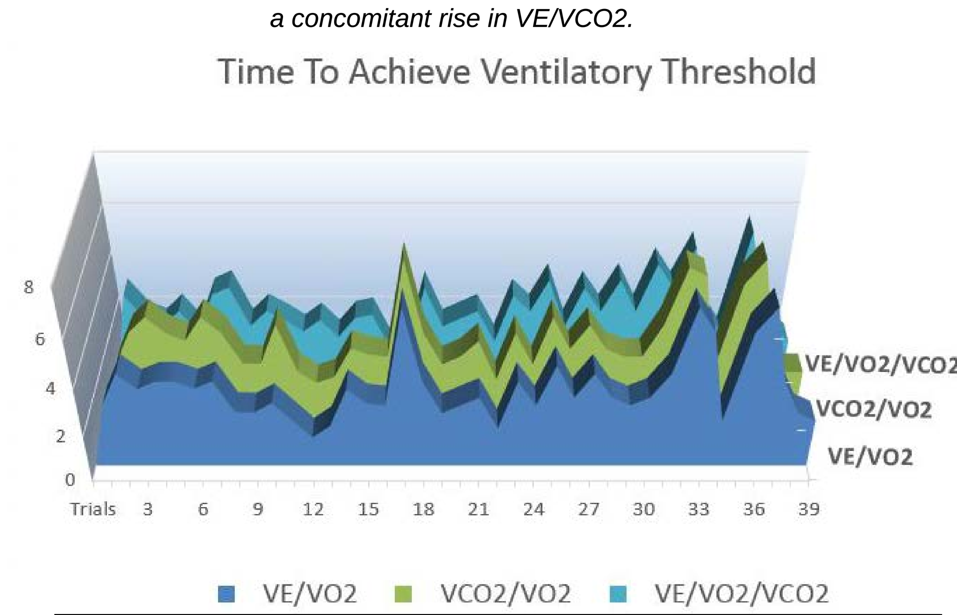
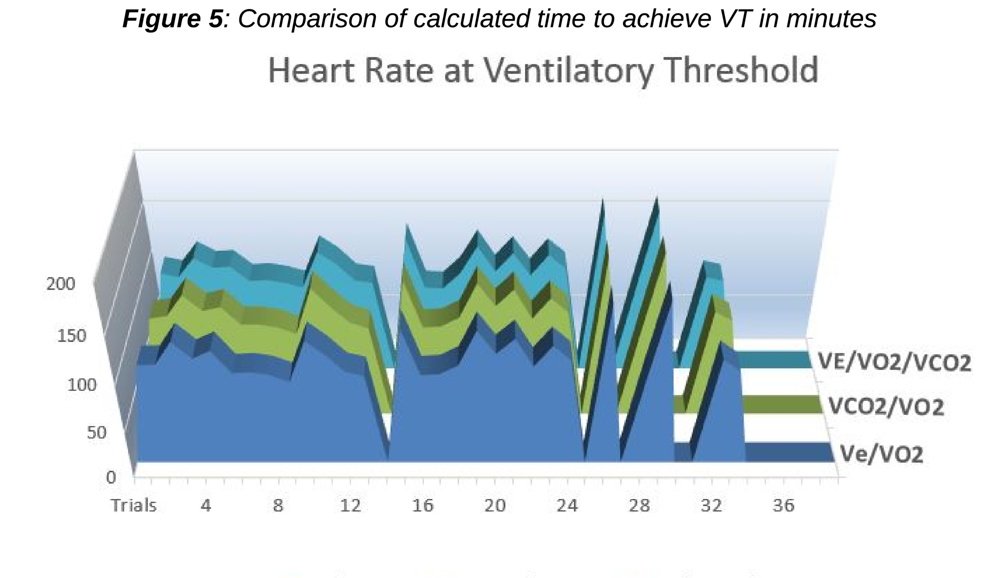


***Figure 3**: Ventilatory Equivalents - The Ventilatory Equivalents Method involves plotting ventilatory equivalent of O2 (VE/VO2) and ventilatory equivalent of CO2 (VE/VCO2) with the anaerobic threshold corresponding to the point at which there is a rise in VE/VO2 without a concomitant rise in VE/VCO2.*



Time to Achieve VT						
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10.78841	2	5.394206	3.268604	0.041656	3.075853
Within Groups	188.1352	114	1.650309			
Total	198.9237	116				

***Figure 5**: Comparison of calculated time to achieve VT in minutes*



HR at VT						
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	168.875	2	84.4375	0.184109	0.832192	3.109311
Within Groups	37148.85	81	458.6278			
Total	37317.72	83				

***Figure 6**: Comparison of subject heart rate once ventilatory threshold was achieved.*

Ventilatory Equivalents method showed an earlier onset compared to the other 2 methods, p = 0.04.

The same analysis using heart rate measurements as a possible indicator of when VT occurs revealed no significant differences between the 3 VT methods, p= 0.83.

Some of the participants for whom we had data were engaged in a 10-week treadmill training program. Since we had pre- and post-intervention VT values for these individuals, we compared changes in VT. Our data showed an increase of 30-40 seconds before VT was achieved, indicating an increase in time before the onset of significant anaerobic metabolism. This change was shown in both the Ventilation Curve and the V-Slope calculation, but was not apparent in the calculations for Ventilatory Equivalents.

Discussion and Conclusions

Our results indicate that using the Ventilation Curve method and the V-slope methods to calculate VT are virtually equal, and that VT onset appears to occur later than VT when calculating it from the Ventilatory Equivalents method. This may indicate that the Ventilatory Equivalents method is more reflective of the first lactate threshold than the second lactate threshold, as noted in previous studies.[1] However, blood samples need to be drawn during testing to verify this.

In addition, the heart rate was found to be similar among the three methods analyzed. A previous study measuring VT in CHF patients showed comparable results for HR at VT.[4] This indicates that HR at VT could be another way to calculate exercise intensity after stroke.

Limitations of this study include that in some cases, there was difficulty obtaining either computational or visual verification of VT from the data. These plots were erratic with no clear delineation to indicate metabolic changes. Deconditioning may play a role in this, as patients with stroke tend to have significant disability. Respiratory issues or an inability to effectively and consistently maintain the required level of exertion could also have affected the data. Finally, all tests were conducted on a treadmill. Cycle ergometry testing[5] may result in less noise in the data and more clear evidence of metabolic shift with increasing workloads.

References

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