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Comparison of a Continuous and Discontinuous GXT on VO_2 in Resistance-Trained and Endurance-Trained Males

BRANDON D. SHEPHERD[†1], FFION G. PRICE[†1], BENJAMIN M. KRINGS[‡2], and JOHNERIC W. SMITH[‡1]

[1]Department of Kinesiology, Mississippi State University, Mississippi State, MS, USA;
[2]Department of Exercise Science, University of Wisconsin-Platteville, Platteville, WI, USA.

[†]Denotes graduate student author, [‡]Denotes professional author

ABSTRACT

International Journal of Exercise Science 15(4): 414-422, 2022. Traditional graded exercise testing to assess maximal oxygen uptake (VO_{2max}) may not well represent resistance-trained athletes due to their unfamiliarity with continuous exercise. For this reason, it is possible discontinuous exercise protocols may better represent the maximum capacity for aerobic metabolism in resistance-trained athletes, in order to provide a more valid assessment of VO_{2max} and risk of developing cardiovascular disease. Purpose: The purpose of this experiment was to compare VO_{2peak} during a continuous and discontinuous modified Bruce protocol in both highly resistance-trained and endurance-trained males. Methods: 19 college-aged males (age: 20.6 ± 1.9 yr, height: 176.5 ± 7.6 cm, weight: 85.0 ± 25.6 kg) of intermediate resistance- or endurance-trained status were recruited for this study. Participants completed a continuous and discontinuous modified Bruce protocol on two visits separated by seven days. Results: A 2x2 one-way ANOVA revealed a significant group main effect for VO_{2peak} (p = 0.004) in which endurance athletes achieved significantly higher VO_{2peak} values compared to resistance-trained athletes. A significant group main effect for RPE was found (p = 0.045) in which endurance-trained reported significantly higher RPE values than the resistance-trained. A significant main effect for protocol for heart rate (p = 0.033) was found in which individuals achieved higher heart rates during the continuous protocol compared to the discontinuous. Conclusion: Although a discontinuous protocol with rest periods between stages is comparable to the exercise mode familiar to resistance-trained athletes, it did not provide any additional benefit to VO_{2peak} values.

KEY WORDS: Aerobic capacity testing, training status, maximal exercise testing, individualized clinical testing

INTRODUCTION

Physiological assessment is paramount in the evaluation of body function to accurately prescribe exercise protocols tailored to an individual. Specifically, $\dot{V}O_{2max}$ is often used to describe the body's maximum capability to utilize oxygen for aerobic metabolism. Aerobic metabolism is responsible for the majority of energy contributions during prolonged steady state exercise, replenishment of phosphocreatine stores, and metabolism of lactate produced during anaerobic exercise (11, 21, 28). $\dot{V}O_{2max}$ can be calculated using the Fick equation as the product of cardiac output ($\dot{Q}$) and the arteriovenous oxygen difference ($(a-\bar{v})O_2$). Additionally, $\dot{Q}$ is calculated as the product of heart rate (HR) and stroke volume, and depicts the amount of blood pumped by the heart in L/min. While $\dot{Q}$ is correlated to the cardiovascular demand during exercise, $(a-\bar{v})O_2$ is correlated to the cellular oxygen extraction during exercise. As aerobic metabolism increases during exercise, oxygen extraction from the blood by metabolically active tissue increases (3) and results in lower oxygen content in venous circulation, representing the metabolic demand of the body. Investigation of the cardiovascular and metabolic parameters of $\dot{V}O_{2max}$ has provided insight toward cardiovascular disease risk (16) and endurance performance capabilities (27).

While several methods exist to estimate $\dot{V}O_{2max}$ in the field (5, 25), directly measuring maximal oxygen uptake remains the gold standard (12). Many protocols have been accredited for accurately measuring $\dot{V}O_{2max}$ (2, 6, 14) and modifications have been developed to better evaluate specific populations and varying demands (16, 25). One alteration to traditional testing has been the addition of a computerized rowing competition by Hagerman for testing trained rowers. This study demonstrated higher $\dot{V}O_{2max}$ values in the rowers during the computerized competition compared to a traditional graded exercise test (GXT), demonstrating a possible need for arousal to reach maximum physiological capabilities (19). In addition to alterations being taken for well-trained athletes, alterations in traditional protocols have also been created to accommodate lower fitness levels in obese individuals (9). It appears that specific populations may require special circumstances to accurately depict maximal oxygen uptake, such as in resistance-trained individuals. To the authors' knowledge, there are currently no recommended individualized protocols for this population, therefore it is of interest to the current study.

High intensity resistance-training is often not considered to be aerobically demanding nor requiring of muscular endurance (36). Traditionally, GXTs assess individuals through continuous aerobic exercise until the subject reaches volitional fatigue. In comparison, resistance exercise is largely intermittent, therefore participants may be unaccustomed to continuous exercise and consequently, not sufficiently prepared for traditional $\dot{V}O_{2max}$ testing. It is possible traditionally used testing protocols may inadequately represent the maximum capacity for aerobic metabolism in resistance-trained athletes, providing only peak oxygen consumption achieved during the testing protocol ($\dot{V}O_{2peak}$) and not a true $\dot{V}O_{2max}$. It is well understood that aerobic metabolism is responsible for the majority of energy contributions during rest and low-to-moderate intensity exercise (20). With increases in exercise intensity, the energy demand exceeds the body's ability to utilize oxygen, resulting in greater contributions from anaerobic processes. Because of this, prolonged high-intensity exercise results in fatigue, through metabolic, neuromuscular, and mechanical inadequacies (15, 30). Highly resistance-trained individuals having a greater anaerobic capacity, may succumb to fatigue through metabolic acidosis before achieving maximal $\dot{Q}$ (30). Some types of resistance training have been shown to improve small levels of aerobic fitness, as an increase in $\dot{V}O_{2max}$ (17, 32). This may be due to its role in phosphocreatine regeneration and lactate utilization between sets even though muscle endurance may not be stressed.

Due to adaptations with resistance training, a discontinuous GXT protocol may more accurately represent maximal oxygen uptake in resistance-trained individuals. Multiple studies have found there to be no differences in $\dot{V}O_{2peak}$ when comparing a discontinuous GXT protocol to a continuous protocol (12, 24, 26, 27). However, Meir et al. demonstrated significantly greater $\dot{V}O_{2peak}$ values in college soccer athletes during a discontinuous protocol compared to a continuous protocol (29). The author attributed the differences to the similarity of a discontinuous protocol to the intermittent bursts found in soccer. Therefore, the purpose of this study was to investigate the differences in $\dot{V}O_{2peak}$ in both endurance and resistance-trained individuals using continuous and discontinuous Bruce protocols. The authors hypothesize that resistance-trained individuals will achieve higher $\dot{V}O_{2peak}$ values during the discontinuous exercise protocol compared to the continuous protocol.

METHODS

Participants

19 college-aged males (age = 20.6 ± 1.9 yr; height = 176.5 ± 7.6 cm; weight = 85.0 ± 25.6 kg) were recruited for this study and were either resistance-trained (RT) or endurance-trained (ET) status. RT (n = 11) was defined as 4 days/week of resistance training exercise with less than 2 hours/week of aerobic exercise (18) for the past six months. To ensure group differences in training background, this study defined ET (n = 8) as aerobic training of greater than or equal to 5 hours/week with less than 3 days/week of resistance activity. Inclusion criteria included representation of one of the two training statuses, low risk according the American College of Sports Medicine guidelines for risk stratification (1). All participants signed an informed consent approved by the Institutional Review Board of Mississippi State University prior to participation.

Protocol

Participants arrived at the Applied Physiology Lab at Mississippi State University for three separate visits. During Visit 1, participants that met the inclusion criteria, signed an informed consent, and then completed a physical activity readiness questionnaire and medical history questionnaire. Researchers followed standardized procedures to collect height using a digital stadiometer (235D, QuickMedical, Issaquah, WA, USA) and body mass using a digital scale (Defender 5000, Ohaus Corporation, Parsippany, NJ, USA). All participants wore compression shorts for height and weight. During Visits 2 and 3, participants completed a Bruce Protocol (35) or discontinuous modified Bruce Protocol on a treadmill (Woodway, Waukesha, WI, USA) with 10-minute rest periods between stages as seen in Table 1. During discontinuous testing participants rested after each completed stage by sitting quietly for 10 minutes before resuming the next stage. Protocol order was randomized for each participant and separated by at least 7 days to ensure there was not a learning effect. Researchers collected respiratory gas measures using a MOXUS metabolic cart, previously validated for $\dot{V}O_2$ measurements (4), (AEI, Pittsburgh, PA, USA) and heart rate was recorded using chest strap heart rate (HR) monitors (H10; Polar Electro Inc., Lake Success, NY). Trials ended when the participant reached volitional fatigue and 30-sec oxygen consumptions values at that point were reported as $\dot{V}O_{2peak.}$ Lastly, rating of perceived exertion (RPE) was collected using the Borg Scale (37) during the last 10 seconds of each stage. The authors attest that they have complied with the ethical statements provided in Navalta et al. 2019 throughout the scientific process (31).

Table 1. Modified Bruce protocol adapted from Stefani et al. 2010.

Stage	Time (min)	Speed (mph)	Grade (%)
1	0:00	1.7	10
2	3:00	2.5	12
3	6:00	3.4	14
4	9:00	4.2	16
5	12:00	5.0	18
6	15:00	5.5	20
7	18:00	6.0	22
8	21:00	6.5	24
9	24:00	7.0	26
10	27:00	7.5	28

Statistical Analysis

A 2x2 ANOVA was used to assess differences in $\dot{V}O_{2peak}$, heart rate, and RPE between endurance-trained and resistance-trained males during a Bruce Protocol as compared to a discontinuous modified Bruce Protocol. Alpha was set a-priori at $p \leq 0.05$ to denote significance. Data analysis was completed using IBM SPSS Version 26 (Version 26, IBM Corporation, Armonk, NY, USA)

RESULTS

The results of this study did not show a significant interaction of training status and exercise protocol ($F(1,34) = 0.328$, $p = 0.571$), and exhibited with a small effect size of $\eta^2_p = 0.010$. There was no significant main effect for the exercise testing procedure between the continuous and discontinuous testing (55.18 ± 15.57 vs. 54.52 ± 14.33 ml/kg/min) ($F(1,34) = 0.105$, $p = 0.748$) with a small effect size of $\eta^2_p = 0.003$ (Figure 1). However, there was a significant main effect for participant training status ($F(1,34) = 75.819$, $p < 0.001$) with a large effect size of $\eta^2_p = 0.690$, in which, the endurance-trained group compared to the resistance-trained group (69.02 ± 7.70 vs. 44.54 ± 8.80 ml/kg/min).

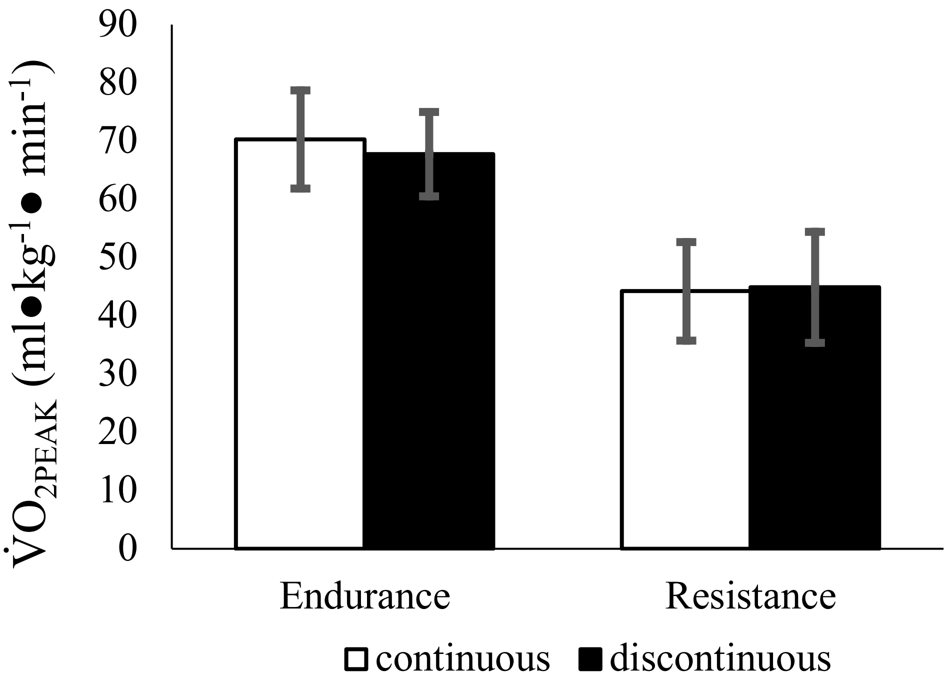

Figure 1. $\dot{V}O_{2PEAK}$ during continuous and discontinuous Graded Exercise Test.

Peak heart rate did not demonstrate a significant interaction between training status and exercise protocol ($F(1,34) = 1.553$, $p = 0.221$), with a small effect size of $\eta^2_p = 0.044$. There was no significant main effect for training status ($F(1,34) = 0.775$, $p = 0.385$) with a small effect size of $\eta^2_p = 0.022$. However, a significant main effect was found for exercise protocol ($F(1,34) = 4.935$, $p = 0.033$) with a moderate effect size of $\eta^2_p = 0.127$, in which, subjects achieved significantly higher heart rates during the continuous exercise protocol compared to the discontinuous protocol (191 ± 9 bpm vs.186 ± 8 bpm).

There was no significant interaction between training status and exercise protocol ($F(1,34) = 2.650$, $p = 0.113$) with a small effect size of $\eta^2_p = 0.072$, nor was a significant main effect for exercise protocol found ($F(1,34) = 0.154$, $p = 0.697$) with a small effect size of $\eta^2_p = 0.005$. However, a significant main effect was found training status ($F(1,34) = 4.313$, $p = 0.045$) with a moderate effect size of $\eta^2_p = .113$, in which, endurance-trained individuals reported significantly higher RPE values upon testing completion (9.25 ± 0.86) compared to resistance-trained individuals (8.41 ± 1.47).

DISCUSSION

The aim of this study was to investigate the differences in $\dot{V}O_{2peak}$ values between a Bruce Protocol and modified Bruce protocol in resistance- and endurance-trained individuals. Many modifications have been made to better accommodate exercise testing of specific populations (22, 24). However, to the authors' knowledge no modifications have been made to accommodate resistance-trained populations. The authors hypothesized that utilization of a discontinuous GXT protocol to assess $\dot{V}O_{2max}$ in resistance-trained individuals may provide a more valid measure of aerobic function in individuals trained in intermittent sport. While multiple investigations of a discontinuous vs. continuous GXT protocol have provided a lack of evidence for the case (12, 24, 26, 27), one study investigating college soccer players demonstrated higher a $\dot{V}O_{2peak}$ with discontinuous testing compared to continuous testing (29). Due to the similarity in the nature of resistance exercise, it is possible resistance-trained individuals may find comparable benefit.

As expected, this study found significantly higher $\dot{V}O_{2peak}$ values in the endurance-trained group compared to the resistance-trained group. Endurance exercise is known to provide adaptations to the heart and muscle that result in improved oxygen utilization during exercise in comparison to resistance training (13, 20). Further, the results from this study did not find any differences in $\dot{V}O_{2peak}$ between the discontinuous and continuous protocols for both the resistance- and endurance-trained groups. These results confirm the myriad of research indicating that utilization of a discontinuous protocol to assess $\dot{V}O_{2max}$ does not provide any additional testing validity (12, 24, 26, 27). While the nature of an intermittent GXT is similar to resistance training, the authors speculate that the length of the seated rest periods that accompanied the discontinuous protocol may have hindered lactate clearance (8). This may have accumulated in higher stages of the protocol, reducing the possible benefits of intermittence. Future investigations should include a blood lactate measurement or provide a low-intensity active recovery period in place of sitting passively.

In this investigation, higher peak heart rates were recorded during the continuous protocol compared to the discontinuous protocol regardless of training status. These findings do not align with Alexander and Mier, who observed higher heart rates during a discontinuous GXT compared to a traditional continuous GXT in college soccer athletes (29). Due to the steady state nature of a Bruce protocol, it is possible that cardiac drift, which is often associated with prolonged steady state exercise, is responsible for the increases in HR seen during the continuous exercise protocol. Cardiac drift is a slow-steady increase in HR that is seen after about 10 minutes of moderate intensity exercise that results as an effort to maintain cardiac output (33). While cardiac drift is caused by a complex combination of central and peripheral factors (1, 10, 22) it is possible that the thermal load created during the continuous protocol is responsible for the higher HR values (34). It is possible that the inclusion of rest periods hindered this effect by allowing the body time to recover from each exercise stage. These finding align with McArdle and colleagues in which discontinuous exercise testing resulted in significantly lower HR_{max} compared to continuous exercise protocols (27). Further, because $\dot{V}O_{2peak}$ did not significantly differ between exercise protocols alongside the differences in peak HR values, it can be inferred that during the discontinuous exercise protocols subjects were maintaining stroke volume and/or increasing ($(a-\bar{v})O_2$). Another possibility is that the reduction in heart rate seen with the inclusion of 10-minute rest periods between stages is simply psychological. Endurance exercise is continuous, so the intermittent nature of the discontinuous protocol may have been off-putting to endurance athletes. While resistance training is intermittent, the duration of rest may have been too long compared to a three to five minute rest period generally seen during a high-intensity resistance training workout. In both instances, participants may have become unmotivated to reach maximum effort during the discontinuous protocol. This explanation would coincide with Hagerman who demonstrated competitive rowers required a virtual competition during a GXT for motivation to achieve a higher $\dot{V}O_{2peak}$ (19).

Lastly, endurance trained individuals reported significantly higher RPE values across both exercise protocols compared to the resistance trained group. RPE has been shown to vary between individuals working at the same intensity (7, 37). Further, the reliability of RPE has been questioned by Lamb et al. in which participants reported conflicting RPE values during two identical graded exercise tests (23). Therefore, it is possible that the differences in RPE observed in the current study are due to the natural variability of the measure and not truly due to training status. The lack of a significant difference in HR between groups fails to provide a physiological explanation to the RPE discrepancies between groups. One explanation for the lower RPE values reported by the resistance trained group may be due to the unfamiliarity with the sensation of fatigue related to maximal aerobic testing. However, it cannot be determined if the lower reported values are due to unfamiliarity, effort, or a combination of both. Due to the lower reported RPE values, it is not for certain that the data gathered from this study effectively illustrate the physiological differences between continuous and discontinuous GXTs in a resistance-trained population.

The data of this current study does not support the hypothesis that a discontinuous GXT will more accurately depict $\dot{V}O_{2peak}$ in a resistance-trained population. Further modification to the discontinuous protocol format should be investigated with shorter rest periods or periods of active recovery to help clear any metabolic by products that may attribute to fatigue at later stages. Further, the reduction in HR exhibited while maintaining $\dot{V}O_{2peak}$ between the continuous and discontinuous exercise protocol should be investigated for clarification of cardiometabolic dynamics associated with the inclusion of a rest period.

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