2-WEEKS OF LOWER BODY RESISTANCE TRAINING ENHANCES CYCLING TOLERABILITY TO IMPROVE PRECISION OF MAXIMAL CARDIOPULMONARY EXERCISE TESTING IN SEDENTARY MIDDLE-AGED FEMALES

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ABSTRACT

It is not uncommon for sedentary individuals to cite leg fatigue as the primary factor for test termination during a cardiopulmonary exercise test (CPET) on a cycle ergometer. The purpose of this study was to examine the effect of two-weeks of lower body resistance training (RT) on cardiopulmonary capacity in sedentary middle-aged females. Additionally, the impact of RT on muscle strength was evaluated. Following familiarization, 28 women (18 exercise, 10 control) completed a maximal CPET on a cycle ergometer to determine peak oxygen uptake ($VO_{2peak}$) and leg extensor strength assessed using isokinetic dynamometry. Participants in the exercise group performed two weeks (6 sessions) of lower body RT consisting of leg press, leg curl, and leg extension exercises. A two-way repeated measures ANOVA was used to evaluate the difference in changes of $VO_{2peak}$ and peak torque (PT). $VO_{2peak}$ significantly improved from $22.2 \pm 4.5 \, \text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ to $24.3 \pm 4.4 \, \text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ (10.8%, $p < 0.05$) as well as PT from $83.1 \pm 25.4 \, \text{Nm}$ to $89.0 \pm 29.7 \, \text{Nm}$ (6.1%, $p < 0.05$) in the exercise group with no change in the controls. These findings provide initial evidence that two-weeks of lower body RT prior to a CPET may be a helpful preconditioning strategy to achieve a more accurate $VO_{2peak}$ during testing, enhancing tolerability to a CPET by improving lower body strength.

Key Words: resistance training; cardiopulmonary capacity; exercise testing; exercise assessment; $VO_{2peak}$; sedentary
INTRODUCTION

The natural aging process results in declines in physiological characteristics including muscle mass, muscular strength, and cardiopulmonary capacity (Lexell et al. 1988; Frontera et al. 1991; Doherty et al. 1993; Fitzgerald et al. 1997). These declines can occur at an increased rate if the individual is sedentary or diagnosed with certain illnesses (heart failure, cancer) (Evans 1995; Roubenoff and Hughes 2000; Fearon and Moses 2002). To alleviate the decrease in muscle mass and strength, resistance training (RT) is an effective intervention that is also associated with improvements in overall physical function (Hanson et al. 2009). Gradual decreases in an individual’s cardiopulmonary capacity, usually expressed as peak oxygen uptake ($\text{VO}_2\text{peak}$), further diminishes the ability to carry out daily tasks (Fleg et al. 2005). In certain illnesses, such as breast cancer, a drop of approximately 30% of $\text{VO}_2\text{peak}$ values is commonly observed when compared to age matched, similar fitness level healthy females (Neil-Sztramko et al. 2014).

Decreases in muscle mass, muscular strength, and cardiopulmonary capacity appear to be related in the context of cardiopulmonary exercise testing (CPET). Muscle mass and strength declines have been associated with decreases in $\text{VO}_2\text{peak}$ in healthy individuals, patients with chronic heart failure, non-athletic populations, and post-menopausal females (Fleg and Lakatta 1988; Neder et al. 1999; Cicoira et al. 2001; Barbat-Artigas et al. 2011). A possible cause of this is premature termination of the CPET due to lower limb fatigue. Individuals are unable to produce the necessary force to overcome the resistance of the pedals. To our knowledge, leg fatigue has been reported as a major reason for test termination at the conclusion of a CPET on a cycle ergometer in men (Midgley et al. 2017). However, we have also observed many healthy females and breast cancer patients cite leg fatigue from previous studies in our lab (Spector et al.
2014; Evans et al. 2015) as opposed to a combination of muscular and cardiopulmonary limitations for terminating a CPET.

To address the issue of lower limb fatigue causing premature termination of a CPET, RT has been used to help alleviate the potential peripheral fatigue commonly observed on a cycle ergometer. Both aerobic and RT have been suggested to improve cardiopulmonary capacity in older sedentary populations with strong relationships being observed in one-repetition maximum (1-RM) scores and muscle fiber area with VO$_{2peak}$ (Frontera et al. 1990; Vincent et al. 2002). In solely female populations, including post-menopausal (Brentano et al. 2008) and breast cancer patients (Rahnama et al. 2010), increases in VO$_{2peak}$ in response to the various types of RT protocols have been reported (12-24 weeks).

Despite their practicality being limited due to their excessive protocol lengths, these results lead us to believe that RT prior to assessing cardiopulmonary capacity may help improve the individual’s tolerability to a CPET. Improvements in VO$_{2peak}$ with short-term RT protocols (4-5 weeks) have been observed (Kim et al. 2011; Falatic et al. 2015; Myers et al. 2015). However, it is unknown if even shorter RT protocols can produce similar results. However, neuromuscular adaptations have occurred in as little as two weeks in response to RT (Moritani and DeVries 1979). The improvements in strength may translate to better performance during a CPET. Short-term adaptations in response to RT have been mechanistically described in two ways: (1) increased motor unit firing frequency, and (2) larger motor unit recruitment; increasing the ability to generate force.

Knowing that there is an established relationship between increases in cardiopulmonary capacity in response to RT and that strength increases are seen in as early as two weeks of training, exploring the impact of this training protocol length is necessary as an attempt to
maximize tolerability during a CPET. The primary purpose of this study was to examine the effect of a two-week lower body RT protocol on VO$_{2peak}$ in sedentary middle-aged females. We hypothesized that VO$_{2peak}$ would significantly increase as a result of the short two-week lower body RT protocol.
MATERIALS AND METHODS

This preliminary study utilized a prospective research design, recruiting 18 subjects to the exercise group followed by 10 subjects to the control group, to examine the impact of two weeks of lower body RT on cardiopulmonary capacity and the efficacy of the familiarization protocol in sedentary middle-aged females. The later recruitment of control subjects allowed for comparisons to those who participated in the exercise portion on the study, but was done separately due to convenience of sample recruitment. Due to the current work in our laboratory involving women with breast cancer and the issue of leg fatigue during a CPET on a cycle ergometer, our team designed the current study to examine a short intervention to “prime” the major muscles involved in cycling. The population chosen is similar in age and physical activity levels to women with breast cancer.

Each subject reported to the laboratory on three separate occasions for testing purposes (Baseline familiarization, Pre-intervention testing, and Post-intervention testing). The first day involved familiarization sessions to the maximal CPET on a cycle ergometer and the lower body isokinetic strength test. The first visit also consisted of 1-RM testing for the determination of the RT training loads. Day two of testing, occurring 2-7 days later, included the maximal lower body isokinetic strength test with electromyography (EMG) assessment of the Vastus Lateralis (VL) and the maximal CPET on a cycle ergometer. Prior to the third day of testing (Post-RT intervention), subjects in the exercise group participated in two weeks of lower body RT. A total of six training sessions were completed with 48 hours of rest between each training visit. Subjects in the control arm were instructed to not change their current physical activity status for the duration of the two weeks. Both groups participated in the third day of testing two weeks later consisting of lower body isokinetic strength testing and the maximal CPET.
Subjects

Twenty-eight sedentary middle-aged females volunteered for the study; exercise group (n=18) and control group (n=10). Subject characteristics are presented in Table I. Subjects were made aware of the project via flyers, emails, phone calls, and face-to-face interaction with research team members. Written informed consent was obtained from all individual participants, and the study was approved by Institutional Review Boards in Exercise and Sport Science and School of Medicine at UNC-Chapel Hill.

Insert Table I about here.

All subjects participating in the study were between 35 to 65 years of age and sedentary. The sedentary criteria for participation in the study was determined by not having participated in regularly scheduled exercise, < 2 times/week, for at least six months prior to beginning the study. Other inclusion criteria for participation included: not having any musculoskeletal disease or injury that would preclude participation in any aspect of the study or cardiopulmonary disease that would put a subject at risk to undergo a maximal CPET. This was determined by medical history questionnaire and an evaluation of a 12-lead resting electrocardiogram by a cardiologist member of the research team.

Procedures

Familiarization
All subjects were familiarized with the testing protocols prior to testing visits to minimize the potential of a learning effect from pre to post intervention testing. Subjects were initially fitted to the dynamometer chair and instructed on proper execution of an isokinetic leg extension. Subjects then performed two sets of three consecutive isokinetic leg extensions at 50% and 75% of their perceived maximal effort. Velocity was set at $60^\circ \cdot \text{second}^{-1}$ for all repetitions. Subjects were then fitted for a respiratory mask for CPET familiarization. Seat height on the cycle ergometer was adjusted for proper cycling pedaling mechanics. Subjects were taken up to 75-85% of their target heart rate determined by heart rate reserve (HRR) method.

Maximal Cardiopulmonary Exercise Test (CPET)

For the assessment of cardiopulmonary capacity, the Astrand Cycle Ergometer Maximal Test Protocol using Parvo Medics TrueMax 2400 Metabolic System (Parvo Medics, Salt Lake City, UT USA) and a Lode electronically braked cycle ergometer (Lode, Gronigen, The Netherlands) were used. Subjects’ respiratory responses were obtained by the use of a Hans Rudolph 7450 Series V2 Respiratory Valve (Hans Rudolph Inc., Shawnee, KS, USA). Rate of perceived exertion (RPE) was assessed using a Borg 6-20 RPE scale. Heart rate was continuously monitored via a Pacer Polar heart rate monitor (Polar Electro Inc., Lake Success, NY USA). The test began at 50 watts with each subsequent stage lasting three minutes with a corresponding increase of 25 watts. Termination of the test was determined by the subjects reaching volitional exhaustion and signaling to stop the test or a VO$_2$ plateau/decrease with increase in exercise intensity. A post CPET lactate measurement was obtained after three minutes using a portable lactate analyzer (Lactate Plus, Sports Resource Group, Hawthorne,
NY). VO₂ data was evaluated to determine if subjects achieved a VO₂ plateau during the last stage of each test, which in turn would indicate if a true VO₂max was achieved.

**Isokinetic Strength Testing**

Prior to beginning the isokinetic strength test, subjects warmed up on a cycle ergometer for five minutes at 50 Watts. The intent of the warm-up was to increase blood flow to the lower-extremities in preparation for the strength assessment. Subjects were then placed in the dynamometer chair (HUMAC Norm Dynamometer, Stoughton, MA) with harnesses placed over the shoulders, waist, and right leg. After skin was lightly abraded and cleaned with isopropyl alcohol, muscle activation was examined using EMG surface electrodes (TSD 150B) that were placed parallel to muscle fibers on the right VL at 66% of the femur length. A ground electrode was placed on the tibial tuberosity of the right knee. Subjects followed same warm up as in the familiarization session and then proceeded to complete three maximal isokinetic leg extensions at a velocity of 60°·second⁻¹ with two minutes of rest between each contraction. The greatest peak torque (100 ms epoch) recorded during the isokinetic load range was used for data analysis.

All signals were collected with a Biopac MP150WSW data acquisition system and AcqKnowledge software (Biopac Systems, Inc., Santa Barbara, CA, USA) at a sampling rate of 2000 Hz. Raw EMG and torque signals were analyzed with Labview 2014 software (Version 14, National Instruments, Austin, TX, USA). A fourth order, zero phase shift low pass 50 Hz Butterworth filter was used to filter the torque and a zero-phase shift bandpass (10 – 500 Hz) fourth order Butterworth filter was used for the EMG signals of the VL. EMG amplitude was calculated using a root mean square function during the entire isokinetic load range. One subject
from both the exercise and control group was excluded due to data collection processing errors with the Biopac data acquisition software during testing.

1-RM Assessment

A 1-RM assessment of the leg press and leg extension was conducted to prescribe the training load for the two-week RT intervention. Hamstring maximal strength was not assessed but the leg curl was included in the RT intervention to balance the RT across both the anterior and posterior musculature of the lower limbs. Verbal instructions of the testing procedures were provided to the subjects prior to assessment. Subjects were fitted to the leg press machine and instructed on proper form. For the leg extension, the knees were aligned with the axis of the machine, and subjects were asked to perform the exercise with their back against the back pad with hands grasping the handles and to not lock their knees during the concentric portion of the exercise.

Subjects were allowed to warm up prior to testing (2 sets for 5-10 repetitions). The tester then asked subjects to rate their effort during the warm-up using an RPE scale so to guide the initial load to be used to determine the 1-RM. The 1-RM value was determined for the leg press and leg extension exercises by performing single repetitions with increasing workload until subjects were unable to complete the lift through a full range of motion. The highest load completed with proper form within five attempts was designated as the 1-RM. Rest periods were two minutes between sets and five minutes between exercises.

Resistance Training

Subjects reported for six training visits (two weeks) with 48 to 72 hours between each visit. Each session began with a five minute cycling warm up at 50 Watts. Subjects then
completed the leg press, leg curl, and leg extension exercises. Initial (sessions one & two) intensity for the exercises were set at 65% of the subjects’ 1-RM. A moderate intensity load (i.e.: RPE of 12-15 on an original Borg scale) for the leg curl exercise was used to provide subjects with hamstring training to counterbalance the training of the quadriceps muscle. Subjects completed two sets of 8-10 repetitions with a two-minute rest between each set. A 10% increase in load was implemented for the third and fourth training session with sets and repetitions remaining the same. For the last two sessions, another 10% increase in load was implemented for the two sets and repetitions range was reduced to 5-10.

**Statistical Analysis**

Data was analyzed with SPSS Statistics version 20.0. The alpha level was set *a priori* for all statistical analyses at 0.05. Descriptive statistics were used in order to exhibit the study population characteristics (age, height, body mass, etc.), and potential baseline differences between the two groups were evaluated via independent samples t-test. A two-way repeated measures analysis of variance (ANOVA) was used to evaluate the differences in the primary outcome variables (VO$_{2\text{peak}}$ and PT) within and between groups both pre and post exercise intervention. A simple regression was performed to examine the relationship between changes in VO$_{2\text{peak}}$ with changes with changes in PT. Exploratory analyses were conducted to compare changes over two weeks in muscle activation (EMG amplitude), VO$_2$ at ventilatory threshold (VT), maximal minute ventilation (Ve$_{\text{max}}$), maximal power output, lactate, and time to exhaustion via dependent and independent t-tests. A pearson correlation was used explore the relationship among changes in VO$_{2\text{peak}}$ with changes in VO$_2$ at VT. Power calculations for the proposed study were completed using G*Power 3.1 software (67) based on sex similarities, RT
protocol length, and the primary outcome variable of VO$_{2\text{peak}}$ (Falatic et al. 2015). With a predicted 10% of performance improvement in VO$_{2\text{peak}}$, the present study achieved statistical power of 0.80 with enrollment of 28 total subjects.
RESULTS

There were no statistically different baseline characteristics between the exercise and control groups (Table I). Both groups were statistically similar when observing baseline performance measures of VO$_{2\text{peak}}$ (p = 0.194) and PT (p = 0.350).

The two-way repeated measures ANOVA revealed a statistically significant interaction between the effects of the exercise and control group on VO$_{2\text{peak}}$ (F = 11.448; p = 0.002) and PT (F = 5.054; p = 0.034). Simple main effects analysis showed that within the exercise group, VO$_{2\text{peak}}$ (10.8%, p = 0.002) and PT (6.1%, p = 0.003) significantly improved from pre to post with no changes in the control group. Significant group differences were observed between exercise and control subjects for VO$_{2\text{peak}}$ (14%, p = 0.002) and PT (13%, p = 0.034) that favored the intervention (Figures I and II). Simple regressions revealed no relationship among changes in VO$_{2\text{peak}}$ with PT (R$^2$ = 0.02; p = 0.619) in the exercise group. No significant changes in muscle activation (p = 0.247) were observed in either group within the two week study period. In observing criteria for VO$_{2\text{peak}}$ tests, 0% of subjects met the criteria for a VO$_2$ plateau for the pre or post CPET which has been postulated as a critical criteria for obtaining a true VO$_{2\text{max}}$.

Insert Table II, Figure I and Figure II about here

Follow up analyses (Table II) revealed that the exercise group significantly increased their lactate levels post-CPET (p = 0.04), VO$_2$ at VT (p = 0.001), time to exhaustion (p = 0.001), maximal power output (p = 0.002), and Ve$_{\text{max}}$ (p = 0.003). Between groups, significant changes were observed for VO$_2$ at VT (p = 0.015), time to exhaustion (p = 0.009), maximal power output (p = 0.002), and Ve$_{\text{max}}$ (p = 0.004). Pearson correlations revealed a strong positive relationship
between VO$_2$ at VT and changes in VO$_{2peak}$ in the exercise group (r = 0.893, p = 0.00) where the control group did not (r = -0.300, p = 0.399).
DISCUSSION

The primary finding of this study demonstrated that lower body RT in as little as two weeks increases VO$_{2\text{peak}}$ and lower limb torque in addition to other cardiorespiratory variables in sedentary older women. Previous research has shown that there is a relationship between VO$_{2\text{peak}}$ and leg strength/leg muscle mass. In older individuals (both male and female), diminished leg muscle mass and leg strength has been associated with age-associated declines in VO$_{2\text{peak}}$ (Fleg and Lakatta 1988; Kostka et al. 2000). In clinical populations, VO$_{2\text{peak}}$/functional capacity has been associated with reductions in leg strength and leg muscle mass in dynapenic post-menopausal women, obese post-menopausal women, and chronic heart failure patients (Cicoira et al. 2001; Barbat-Artigas et al. 2011; Dulac et al. 2018). Through our own observations in our lab (Spector et al. 2014; Evans et al. 2015), leg fatigue is commonly cited as a limiting factor during CPETs performed on a cycle ergometer similar to that seen in males (Midgley et al. 2017). This could be attributed to the inability of the individual to generate an adequate amount of force to overcome the resistance in the pedals (Neder et al. 1999). Furthermore, no subjects (control or exercise) in our sample met the criteria for a VO$_2$ plateau during the incremental CPET, leading us to believe that a true VO$_{2\text{max}}$ was not achieved during our testing.

Previous studies have shown a positive impact with RT on VO$_{2\text{peak}}$ despite their practicality being limited due to their excessive protocol lengths (Frontera et al. 1990; Vincent et al. 2002; Brentano et al. 2008; Kim et al. 2011; Falatic et al. 2015; Myers et al. 2015). Knowing that strength gains can be observed in those that are untrained as early as two weeks (Moritani and DeVries 1979), this approach could be utilized to improve cycling VO$_{2\text{peak}}$ in older, sedentary, or clinical populations who often suffer decreases in both leg muscle mass and strength (Kuta et al. 1970; Frontera et al. 1991; Battaglini et al. 2012). To our knowledge, this
study is the first of its kind to examine a very short RT protocol (length of two weeks) on cardiopulmonary capacity in middle-aged sedentary women. This study was done to better characterize cardiopulmonary capacity in this female population by seeking to alleviate the loss of strength commonly observed in this population.

In the present study, a 10% increase in VO$_{2\text{peak}}$ from pre to post intervention was observed in the exercise group whereas the control remained unchanged. Despite a significantly shorter training protocol, changes in VO$_2$ with exercise in the current study were similar, if not greater, than previous studies that utilized interventions ranging from 12 to 24 weeks (Frontera et al. 1990; Vincent et al. 2002; Brentano et al. 2008). Shorter RT protocols (4-5 weeks) reporting increases in VO$_{2\text{peak}}$ (5-11% increase) were similar if not less than the present study. Considering the practical application of the protocol lengths of these studies compared to the present study’s protocol that produces similar changes in VO$_{2\text{peak}}$, this would suggest that longer interventions are not necessary to increase the VO$_{2\text{peak}}$ of a middle to older aged individual when assessed on a cycle ergometer. Rather, two weeks of training could provide a feasible approach to priming the lower limbs in preparation for a CPET, eliciting increases in VO$_{2\text{peak}}$ similar to those studies implementing longer protocols.

The potential mechanisms responsible for the increases in VO$_2$ in this study are unclear. Our data showed that those who performed RT were able to produce more force in the lower limbs as opposed to improving metabolically (Neder et al. 1999). In response to two weeks of training, an increase in neural activation recruits and activates more muscle fibers and leads to greater muscular force, allowing for the participant to exert a greater power output while pedaling (Kostka et al. 2000). Specifically, an increased recruitment of Type II fibers can result in increased power output, which can be seen with the increase in wattage the intervention group
experienced after the lower body RT. When considering cycling efficiency during submaximal intensities during the CPET at baseline and post lower body RT, no differences in oxygen uptake were observed. This leads us to believe that the neural adaptation (ie., increased Type II fiber recruitment) rather than histochemical changes resulted in greater power output and a higher VO$_2$\textsubscript{peak} on the second CPET for the exercise group. In the present study, the exercise group did elicit both a significant increase in VO$_2$\textsubscript{peak} as well as torque during a isokinetic leg extension whereas the control did not. It is plausible to attribute the increase in VO$_2$\textsubscript{peak} values to the increase in lower body strength that was observed in response to the two weeks of RT. However, two pieces of evidence argue against this. First, neither group displayed significant changes from pre- to post-training in EMG activity during the maximal isokinetic leg extension test. Second, no relationships were observed between the changes in VO$_2$\textsubscript{peak} and changes in isokinetic torque and EMG activity, suggesting that other factors may be responsible improvements in VO$_2$\textsubscript{peak}.

Despite the exercise group improving while the control group did not, the lack of observed relationships in the changes of performance variables makes it hard to solely attribute the improvements in VO$_2$\textsubscript{peak} to the RT protocol. However, the lack of relationship may be a result of study design, rather than lack of improvement. Muscle activity was only assessed on the VL during the isokinetic leg extensions. This hampered our ability to discern the contributions from the other knee extensors along with coactivation in the knee flexors. Coactivation occurring in the antagonist muscles potentially blunted the training effect that occurred in the VL in response to the intervention. Though not examined, activation of the hamstrings was likely reduced during the post-test in the current study, resulting in less resistance to knee extension movements (and greater torque) without any change in activation. This phenomenon has been
reported previously in response to eight weeks of lower body isometric training (Carolan and Cafarelli 1992). Although muscle activation remained unchanged in the present study, the observed increases in VO$_{2\text{peak}}$ and PT do indicate a training effect in that subjects were able to exert themselves to a greater extent during the post CPET.

Further analysis of the graded CPETs were analyzed as well. A subjective assessment on reasons for terminating the CPET was completed. 26 of the 28 subjects indicated that leg fatigue played a primary role in terminating the pre-CPET. The two subjects that did not indicate leg fatigue as a primary contributor were in the control group. When asked why they decided to terminate the post-CPET, 14 out of 18 subjects in the exercise group indicated that breathing played an increased role in terminating the test, providing circumstantial evidence that leg fatigue was reduced in response to the completed RT. Compared to the control group where all answers were unchanged from pre to post, this subjective analysis suggests the RT had a significant impact.

Subjects in the exercise group significantly improved peak wattage during the CPET, $V_{e_{\text{max}}}$, increased VO$_2$ at VT, and time to exhaustion with training. Changes in VO$_{2\text{peak}}$ were strongly correlated with changes in VO$_2$ at VT as well. Taking into consideration the improvement in torque production that was observed in response to training, improvement in power output during the CPET is a logical conclusion. The decrease in leg fatigue that occurred during the post-CPET for subjects in the exercise group may be attributed to the enhanced ability to further recruit type II fibers, which can be attributed to the increase in lactate production.

Certain limitations of this study may have impacted the results. The subjects in this study were not randomized. However, the addition of a non-exercise control group included after preliminary results indicated RT had an effect on VO$_{2\text{peak}}$ allowed for better interpretation of the
study results. The control group remaining unchanged provides additional evidence supporting future studies to explore short-term RT as a mean to improve VO$_{2\text{peak}}$ in this population in a larger randomized controlled trial. Another potential confounder was the lack of familiarization on the leg press and leg extension 1-RM exercises. However, the 1-RM values were used to only determine the intial training loads. With significant improvements in PT following RT and no change in controls would suggest that the intervention was still effective. The use of 1-RM familiarization may help for more precise determininations of training loads that could affect PT outcome and ultimately VO$_{2\text{peak}}$ for future studies.

These findings demonstrate that a lower body RT program appears to improve VO$_{2\text{peak}}$ in sedentary midle-aged females in as little as two weeks. We provide preliminary evidence for practitioners to attempt a short RT program prior to a CPET, particularly if a true peak value is required. By priming the muscles that are predominantly used when cycling, the tolerability to a CPET can be significantly improved. Subjects were able to pedal longer, produce more power, and consume more oxygen in the present study. Given that clinical populations are not primarily made up of trained cyclists, this approach may produce a more accurate representation of their cardiopulmonary capacity. This in turn could assist with constructing more precise aerobic exercise prescriptions on a cycle ergometer.

Conflicts of Interest: ER has research contracts with Naturex SA and NC Public Safety. WW has received research support from Genentech.
References


Midgley, A.W., Earle, K., McNaughton, L.R., Siegler, J.C., Clough, P., and Earle, F. 2017. Exercise tolerance during VO2max testing is a multifactorial psychobiological


Figure I Caption

mean (+/- SD)
*Significantly different from baseline within respective group (p < 0.05)
†Change scores significantly different between groups (p < 0.05)

Figure II Caption

mean (+/- SD)
*Significantly different from baseline within respective group (p < 0.05)
†Change scores significantly different between groups (p < 0.05)
### Table I: Subject Characteristics (mean ± SD)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th><strong>EXERCISE</strong> (n=18)</th>
<th><strong>CONTROL</strong> (n=10)</th>
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<tr>
<td>Age (years)</td>
<td>53.6 ± 7.2</td>
<td>52.6 ± 8.5</td>
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<tr>
<td>Height (cm)</td>
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<tr>
<td>Pre-Weight (kg)</td>
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<td>Post-Weight (kg)</td>
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<td>BMI (kg·m⁻²)</td>
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### Table II: Performance Outcome Variables (mean ± SD)

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<th>Outcome Variable</th>
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<th><strong>CONTROL</strong></th>
<th><strong>CHANGE</strong></th>
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<tr>
<td>VO₂peak (L·min⁻¹)</td>
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<td>1.9 ± 0.3</td>
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<td></td>
<td>1.9 ± 0.5</td>
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<td>VO₂ at VT (ml·kg⁻¹·min⁻¹)</td>
<td>11.1 ± 3.1</td>
<td>13.3 ± 3.5</td>
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<td></td>
<td>12.4 ± 4.0</td>
<td>12.5 ± 3.9</td>
<td>0.1</td>
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<td>Time to Exhaustion (min)</td>
<td>12.8 ± 2.9</td>
<td>13.8 ± 2.7</td>
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<td></td>
<td>13.5 ± 3.0</td>
<td>13.4 ± 2.9</td>
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<tr>
<td>Maximal Power (Watts)</td>
<td>116.7 ± 22.7</td>
<td>127.8 ± 20.8</td>
<td>11.1‡</td>
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<td></td>
<td>122.5 ± 29.9</td>
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<td>Lactate (mmol/L)</td>
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<td></td>
<td>7.5 ± 1.7</td>
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<tr>
<td>Ve₉max (L/min)</td>
<td>64.1 ± 14.8</td>
<td>72.4 ± 14.9</td>
<td>8.3†</td>
</tr>
<tr>
<td></td>
<td>71.7 ± 17.0</td>
<td>68.5 ± 16.9</td>
<td>-3.2</td>
</tr>
<tr>
<td>Heart Rate Max (b/min)</td>
<td>161.2 ± 17.4</td>
<td>165.6 ± 18.1</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>163.9 ± 15.1</td>
<td>161.1 ± 14.3</td>
<td>-2.8</td>
</tr>
<tr>
<td>% Heart Rate Max</td>
<td>96.1%</td>
<td>99.5%</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>97.9%</td>
<td>96.2%</td>
<td>-1.7</td>
</tr>
<tr>
<td>VL EMG Activation (%)</td>
<td>100</td>
<td>101.3</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>102.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Leg Press 1-RM (kg)</td>
<td>108.9 ± 42.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Extension 1-RM (kg)</td>
<td>76.1 ± 25.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significantly different from baseline within respective group (p < 0.05)
†Change score significantly different between groups (p < 0.05)
Figure I. Pre/post mean scores for VO\textsubscript{2peak}

![Bar chart showing pre and post VO\textsubscript{2peak} scores for Exercise and Control groups.](chart.png)
Figure II. Pre/post mean scores for Peak Torque (PT)