Incidence of Non-Response and Individual Patterns of Response Following Sprint Interval Training

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Abstract

The current study sought to explore the incidence of non-responders for maximal or submaximal performance following a variety of sprint interval training (SIT) protocols. Data from 63 young adults from 5 previously published studies were utilized in the current analysis. Non-responders were identified using 2 times the typical error (TE) of measurement for VO\textsubscript{2peak} (2 x TE = 1.74 mL/kg/min), lactate threshold (2 x TE = 15.7 W), or 500 kcal time to completion (TTC; 2 x TE = 306 secs) trial. TE was determined on separate groups of participants by calculating the test re-test variance for each outcome. The overall rate of non-responders for VO\textsubscript{2peak} across all participants studied was 22% (14/63) with 4 adverse responders observed. No non-responders for VO\textsubscript{2peak} were observed in studies where participants trained 4 times per week (n=18), while higher rates were observed in most studies requiring training 3 times per week (30-50%; n=45). A non-response rate of 44% (8/18) and 50% (11/22) was observed for the TTC test and lactate threshold, respectively. No significant correlations were observed between the changes in VO\textsubscript{2peak} and TTC (r = 0.014; p = 0.96) or lactate threshold (r = 0.17; p = 0.44). The current analysis demonstrates a significant incidence of non-responders for VO\textsubscript{2peak} and heterogeneity in the individual patterns of response following SIT. Additionally, these data support the importance of training dose and suggest that the incidence of non-response may mitigated by utilizing the optimal dose of SIT.

Key words: High-intensity interval training (HIIT), exercise dose, VO\textsubscript{2peak}, lactate threshold, submaximal performance, time trial, non-responder, adverse responder, typical error, individual response.
Introduction

Sprint interval training (SIT), a subclass of high intensity interval training (HIIT) requiring participants to complete brief maximal efforts separated by periods of rest (Sloth et al. 2013), has garnered recent attention as a time efficient alternative to endurance training (END) (Gillen and Gibala 2014). On a group level, SIT induces similar improvements to END for VO$_2$peak (Gist et al. 2013, Sloth et al. 2013), lactate threshold (Esfarjani and Laursen 2007, Zelt et al. 2014), and submaximal performance (Gibala et al. 2006, MacPherson et al. 2011, Scribbans et al. 2014a). While our group, and others, have repeatedly demonstrated the benefits of both SIT and END at a group level, there is increasing evidence that there is substantial heterogeneity in how individual participants respond to exercise training.

Bouchard et al. (1999) demonstrated a heterogeneity in changes in aerobic capacity (VO$_2$peak) following END with some participants exhibiting large improvements and others experienced minimal or no gains. Non-responses to END has also been observed for indices of submaximal performance (anaerobic/lactate threshold, submaximal exercise heart rate, time trial performance) (Vollaard et al. 2009, Scharhag-Rosenberger et al. 2012). Although recent estimates suggest the incidence of non-responders to END for VO$_2$peak is between 20 and 45% (Sisson et al. 2009) it is important to note that there are few individuals who do not respond positively to END by either increasing maximal (VO$_2$peak), or submaximal performance (Vollaard et al. 2009, Scharhag-Rosenberger et al. 2012).

A recent meta-analysis suggests that the individual VO$_2$peak responses to HIIT are likely comparable, if not superior to those observed following END (Bacon et al. 2013). Accordingly, it has been hypothesized that higher intensities of exercise may induce adaptation in individuals with low sensitivity to END (Buford et al. 2013). While these studies suggest that the high
exercise intensities associated with SIT may induce adaptations in more individuals, non-
responders for VO$_2$peak following SIT have been observed following brief (6 training sessions
over 2 weeks) SIT protocols (Astorino and Schubert 2014). Individual patterns of response
across VO$_2$peak and indices of submaximal performance were observed (Astorino and Schubert
2014). Importantly, this study identified non-responders using previously published co-efficient
of variations, an approach that has also been utilized by others (Scharhag-Rosenberger et al.
2010), but fails to consider both biological and technical error within the lab examining the rates
of response to training. Recently, more critical approaches to determining cut-points for
identifying non-responders that consider both biological and technical error, and should
minimize the risk of misidentifying responders as non-responders and *vis versa*, have been
proposed (Hopkins 2000, Bouchard et al. 2012). Thus, despite the substantial evidence
supporting the efficacy of SIT on a group level, the incidence of non-responders for maximal
(VO$_2$peak) and submaximal performance has not been established using statistically sound cut-
points, nor has the incidence of non-response and individual patterns of response been examined
following training interventions lasting more than 2 weeks.

As the awareness of the individual variability in the responsiveness to END grows, and
SIT continues to increase in popularity, there is a need for more information regarding the rates
of non-response following SIT such that we can move towards personal/optimal exercise
prescription. Thus, the primary purpose of the current study was to examine the incidence of
non-response in VO$_2$peak across a range of SIT protocols ranging from 3-6 weeks in duration
utilizing a critically established cut-point for the identification of non-responders. Individual
patterns of non-response were also examined following SIT by comparing individual changes in
VO$_2$peak with changes in lactate threshold or submaximal performance.
Materials and Methods

Data from a total of 63 young adults from 5 previously published studies (Boyd et al. 2013, Ma et al. 2013, Scribbans et al. 2014a, 2014b, Zelt et al. 2014) were utilized in the current analysis (all 5 studies are described briefly below). Novel experiments were also conducted in order to determine the typical error (TE) of measurement for \( \text{VO}_2 \text{peak} \), lactate threshold, and a 500 kcal time to completion (TTC) trial. All experimental procedures performed were approved by the Health Science Human Research Ethics Board at Queen’s University and confirmed to the Declaration of Helsinki. Verbal and written explanation of the experimental protocols and associated risks were provided to all participants prior to their provision of written informed consent.

Data Collection for Previously Published Studies

For all studies, \( \text{VO}_2 \text{peak} \) was determined using an incremental ramp test to volitional fatigue performed on a cycle ergometer (Monark, Ergomedic 874E, Varberg, Sweden) with gas exchange being collected throughout the test using a metabolic cart (Moxus, AEI technologies, Pittsburgh, PA). This protocol has been described in detail elsewhere (Edgett et al. 2013a). Two studies utilized a 500 kcal time to completion (TTC) trial (Boyd et al. 2013, Scribbans et al. 2014a) that required participants to cycle at a self-selected cadence against a load expected to elicit 50% of \( \text{VO}_2 \text{peak} \) work rate at 60 PRM (Jeukendrup et al. 1996). One study (Zelt et al. 2014) calculated lactate threshold using the first recorded work rate with lactate >4mmol/L method (Bishop et al. 1998) from fingertip capillary blood samples collected within the last 10 seconds of each step of the \( \text{VO}_2 \text{peak} \) protocol. Lactate was analyzed using a Lactate Scout + (EFK Diagnostics, Magdeberg, Germany).
Boyd et al., 2013

One subset of the participants from this study was utilized in the current analysis. This subset consisted of overweight/obese, sedentary men (n=9; age, 22.7±3.8 yrs; BMI, 32.3±1.9 kg/m²; VO₂peak, 35.4±5.7 mL/kg/min). VO₂peak and TTC trials were performed before and after training. Training consisted of 3 sessions per week for 3 weeks, utilizing an interval protocol of 8-10 1-minute intervals at ~100% maximal aerobic power separated by 1 minute of loadless cycling.

Ma et al., 2013

Recreationally active men (n=8; age, 20.6±1.6 yrs; BMI, 24.6±1.0 kg/m²; VO₂peak, 40.5±3.8 mL/kg/min) trained 4 times per week with VO₂peak being measured before and after 4 weeks of training. Training consisted of 8, 20 second intervals targeting 170% of peak aerobic power separated by 10 seconds of rest for a total training duration of 4 minutes.

Scribbans et al., 2014a

One subset of recreationally active participants from this study were used in the current analysis. This subset (n=10; 2 female; age, 21.0±2.0 yrs; BMI, 23.0±3.9; VO₂peak, 48.3±6.1 mL/kg/min) trained 4 times per week with VO₂peak and TTC trials being performed before and after 6 weeks of training. Training consisted of 8, 20-second intervals targeting ~170% of peak aerobic power separated by 10 seconds of rest for a total training duration of 4 minutes.

Scribbans et al., 2014b

This study compared the impact of Resveratrol supplementation on training induced increases in VO₂peak. Because no training induced differences in VO₂peak were observed between conditions, data from all participants (placebo and Resveratrol) completing both pre- and post-training VO₂peak tests, and the corresponding time to completion test has been included.
in the current analysis. Recreationally active men (n=14; age, 21.6±1.0 yrs; BMI, 23.3±2.2; VO₂peak, 50.0±5.6 mL/kg/min) trained 3 times per week for 4 weeks and VO₂peak was measured before and after training. Training consisted of 8, 20-second intervals targeting ~170% of peak aerobic power separated by 10 seconds of rest for a total training duration of 4 minutes.

Zelt et al., 2014

Two subsets of recreationally active male participants from this study were used in the current analysis. Both subsets trained 3 times per week for 4 weeks with VO₂peak and lactate threshold measured before and after training. The first subset (n=12; age, 22.0±2.0 yrs; BMI, 26.0±3.0 kg/m²; VO₂peak, 44.2±8.7 mL/kg/min) performed 4-6, 15-second intervals per training session. The second subset (n=10; age, 23.0±5.0 yrs; BMI, 25.0±3.0 kg/m²; VO₂peak, 49.8±7.8 mL/min) performed 4-6, 30-second intervals per training sessions. All intervals for both subsets required an all-out effort and were performed against a resistance equal to 7.5% body weight.

**Determination of Typical Error**

In order to determine TE for VO₂peak and lactate threshold, 8 recreationally active participants (age, 21.0±0.8 yrs; BMI, 21.0±2.3 kg/m²; VO₂peak, 44.4±5.6 mL/kg/min) reported to the lab on 2 separate occasions separated by at least a week. On each visit to the lab participants performed identical incremental ramp tests to volitional fatigue as described above and reported in detail previously (Edgett et al. 2013b, Zelt et al. 2014). Both VO₂peak and lactate threshold were determined for each test and the resulting values were utilized to calculate TE. A similar experiment was performed to determine TE for the 500 kcal time to completion (TTC) trial. Fifteen recreationally active individuals (age, 19.2±0.9 yrs; BMI, 24.0±2.8; VO₂peak, 42.9±8.2 mL/kg/min) reported to the lab on 3 separate occasions. During their first
visit participants performed a VO\textsubscript{2peak} test to determine the appropriate work rate for the subsequent TTC tests. On the 2 subsequent visits, which were separated by at least a week, participants performed a 500 kcal TTC test as described above and reported previously (Boyd et al. 2013, Scribbans et al. 2014a). The TTC for each test was used to calculate TE for the TTC test.

Typical error (TE) of measurement was calculated for VO\textsubscript{2peak}, lactate threshold and TTC as described previously (Hopkins 2000) utilizing the following equation (TE= SD\textsubscript{diff}/√2):

\[
TE = \frac{SD_{diff}}{\sqrt{2}}
\]

Where SD\textsubscript{diff} is the variance (standard deviation) of the difference scores observed between the 2 repeats of each test. A non-responder for VO\textsubscript{2peak}, lactate threshold or TTC was defined as an individual who failed to demonstrate an increase or decrease that was greater than 2x the TE away from 0. The odds of an individual change that is greater than 2x the TE being a true physiological change are 12:1 (Hopkins 2000).

**Statistical Analysis**

Data are expressed as means and standard deviations. Changes in VO\textsubscript{2peak}, lactate threshold and TTC tests at the group level within individual studies were analyzed using paired t-tests. Relationships between the response in VO\textsubscript{2peak} and either lactate threshold or TTC was assessed using the Pearson correlation coefficient as was the relationship between baseline VO\textsubscript{2peak} and the change in VO\textsubscript{2peak} following training.

**Results**

Typical error (TE) was ±0.87 (2 x TE = 1.74) mL/kg/min for VO\textsubscript{2peak}, ±7.8 (2 x TE = 15.7) watts for lactate threshold and ±153 (2 x TE = 306) seconds for the 500 kcal TTC test.
A summary of results from each study utilized in the current analysis, including both
group responses and the incidence and proportion of non-responders, are presented in Table 1.
The magnitude of individual responses for VO\textsubscript{2}peak, relative to TE, is presented in Figure 1A.
The overall rate of non-responders for VO\textsubscript{2}peak across all participants studied was 22% (14/63).
Interestingly, 4 adverse responders (individuals whose VO\textsubscript{2}peak decreased by more than 2 x TE)
were observed. In the 2 studies where participants trained 4 times per week (Ma et al. 2013,
Scribbans et al. 2014a) no non-responders for VO\textsubscript{2}peak were observed. In studies where
participants trained 3 times per week relatively high rates of 31% (4/13) (Scribbans et al. 2014b),
50% (5/10; 30 second SIT) and 30% (4/12; 15 second SIT) (Zelt et al. 2014) were observed. The
exception to these high rates of non-response for studies utilizing 3 training sessions per week
was the study where SIT consisted of 1 minute intervals performed at 100% of maximal aerobic
power (no non-responders were observed in this study) (Boyd et al. 2013). A significant
correlation ($r = 0.52; p<0.001$) was observed between individual baseline VO\textsubscript{2}peak and the
change in VO\textsubscript{2}peak observed following training.

The incidence of non-responders for the TTC test and lactate threshold are presented in
Table 1, while the relationships between the change in VO\textsubscript{2}peak and TTC and lactate threshold
are presented in Figure 1B and 1C respectively. No significant correlations were observed
between the changes in VO\textsubscript{2}peak and TTC ($r = 0.014; p = 0.96$) or lactate threshold ($r = 0.17; p =
0.44$). A non-response rate of 44% (8/18) was observed for the TTC test while 50% (11/22) of
participants failed to increase lactate threshold. An increase in VO\textsubscript{2}peak was observed for all
participants who failed to demonstrate an increase for TTC (Figure 2). Of the 11 individuals
who demonstrated a non-response for lactate threshold, only 6 exhibited an increase in VO\textsubscript{2}peak
(Figure 3). None of the individuals demonstrating an adverse response for either VO\textsubscript{2}peak or
lactate threshold demonstrated an adverse response for another variable; however, 1 participant was an adverse responder for VO\textsubscript{2}peak and a non-responder for lactate threshold (see participant 16 in Figure 3).

**Discussion**

The major findings from the current analysis revealed that: i) a significant proportion of individuals demonstrate a non-response following 4-6 weeks of SIT, ii) non-responders were not observed when SIT was performed 4 times per week or when intervals were performed at 100% of maximal max aerobic power for 1 min, and iii) individual patterns of response were observed across changes in VO\textsubscript{2}peak and submaximal performance, however, there were 5 individuals who failed to improve either VO\textsubscript{2}peak or lactate threshold raising the possibility that there may be global non-responders to SIT.

**Incidence of non-responders for VO\textsubscript{2}peak**

The current data demonstrates a significant incidence of non-responders (22% overall) following 3-6 weeks of SIT. The incidence of non-response in the current study was determined using TE (Hopkins 2000), a parameter that considers both the biological variability and the technical error of measurement observed within a given laboratory and provides a robust and conservative threshold for the determination of individual response (Bouchard et al. 2012). In the present study, the overall incidence of non-response (22%) is consistent with previous reports following both END (20-45%) (Sisson et al. 2009, Scharhag-Rosenberger et al. 2012) and 2 weeks of SIT (35%) (Astorino and Schubert 2014). Importantly, our results confirm a relatively high incidence of non-response following SIT when TE, rather than previously published coefficient of variations, are used to define a non-responder. While these results suggest that the
incidence of non-response following END and SIT are likely similar, there is a need for future studies designed to specifically address this issue. Further, while our results contradict the suggestion that HIIT/SIT might induce superior individual results than END (Bacon et al. 2013), whether individuals who are insensitive to END might respond to SIT remains an important area for future study.

An important observation from the current study is the striking difference in the incidence of non-response following protocols that required participants to train three (Scribbans et al. 2014b, Zelt et al. 2014) compared to four (Ma et al. 2013, Scribbans et al. 2014a) times per week. The incidence of non-response for SIT 3 times per week was 37%; in contrast, no non-responders were observed when SIT was performed 4 times per week. Further, the group changes in VO_{2\text{peak}} when SIT was performed 4 times per week were greater than that observed following 3 times per week SIT (See Table 1), and greater than is typically observed following SIT (Gist et al. 2013, Sloth et al. 2013). These results suggest that there is a threshold of SIT training stimuli above which a greater percentage of individuals will respond. While the exact dose of SIT required to reach this threshold remains unclear, it would appear that training 4 times per week is an important consideration. Contrary to the idea that training 4 times per week is required to minimize the incidence of non-responders is the observation that participants completing a much larger dose of near maximal SIT (1 min intervals at 100% WR_{\text{peak}}) 3 times per week all increased VO_{2\text{peak}} (Boyd et al. 2013). These observations are consistent with the findings from DREW that the incidence of non-responders decreases with increasing training dose (Sisson et al. 2009). While it must be noted that the participants completing this protocol were overweight/obese, reported being sedentary prior to starting training, and had the lowest baseline VO_{2\text{peak}} (which, in the current analysis was negatively associated with the change in
VO₂peak across all participants), it is unclear if this would have impacted their response given the controversy surrounding whether baseline VO₂peak influences the magnitude of increase in VO₂peak following training (Timmons 2011).

Taken together, the finding that a negligible incidence of non-response in VO₂peak is present following SIT training four times per week, or three times per week with a relatively high SIT dose, suggests that greater exercise stimuli (i.e. increase training frequency or dose) may reduce the number of non-responders to training, perhaps by eliciting adaptation in individuals with a low sensitivity to exercise (Buford et al. 2013).

**Individual patterns of response following SIT**

While non-responders for VO₂peak following END have been observed, there is increasing evidence supporting individual patterns of response whereby individuals who do not demonstrate an increase in VO₂peak are likely to improve in other variables typically associated with training. For example, adverse responders for cardio-metabolic disease risk factors were found to have similar increases in VO₂peak as non-adverse responders (Bouchard et al. 2012), and few individuals demonstrate a non-response for both VO₂peak and submaximal performance (Vollaard et al. 2009, Scharhag-Rosenberger et al. 2012). The current analysis demonstrates that individual patterns of response across VO₂peak and submaximal performance are also present following SIT, a finding that is consistent with the END literature, and a previous demonstration of individual patterns of response following two weeks of SIT (Astorino and Schubert 2014). Interestingly, we have also observed a relatively high incidence (23%) of individuals who failed to increase either VO₂peak or lactate threshold following four weeks of SIT three times per week. It is important to note, that these “global” non-responders completed SIT requiring a very low training dose (4-6, 15-30 second intervals 3 times per week), with the majority (4/5) of these
“global non-responders” being individuals from the 15 second interval group. This provides further evidence supporting the importance of training dose for reducing the incidence of non-responders to SIT.

An interesting consideration, which unfortunately could not be addressed in the current analysis, is the impact of individual effort on the adaptations induced by SIT. Unlike many HIIT protocols and most END protocols where a specific workload and total volume of work is prescribed in each training session, SIT allows the peak power and total work performed during each training session to vary based on individual fitness and effort. Thus, it is possible that those individuals who don’t respond to SIT are simply the individuals who put in the least amount of effort. While it is unlikely that this explains all individual variability following SIT, individual effort should be considered/measured in future SIT studies.

**Conclusion**

At present, while there is emerging evidence demonstrating the incidence of non-response following END, there is limited data available regarding non-response following SIT. The current analysis demonstrates significant incidence of non-responders for VO\textsubscript{2}peak following SIT. Further, we confirmed a similar heterogeneity in the individual patterns of response following SIT and following END. Importantly, the incidence of non-response was highest following SIT protocols that required the lowest training volume, highlighting the importance of training dose (i.e. training session energy expenditure and/or training frequency) and supporting the potential that incidence of non-response may be reduced once the training-dose threshold of SIT is reached. Future work is needed to both compare incidences of non-response following END and SIT, to compare the incidence of non-response to SIT in men and women, and to determine the optimal dose of SIT for minimizing individual non-response.
These results contribute to a growing awareness of individual responsiveness to exercise training by demonstrating a significant rate of non-response following SIT and by highlighting the potential impact optimization of SIT (i.e. training frequency/duration) might have on minimizing the risk of non-response following exercise prescription.

Conflict of Interest

The authors declare that there are no conflicts of interests associated with this manuscript.
Reference List


Table 1. Baseline and training induced changes in VO2peak, lactate threshold and time to completion (TTC) for the 5 studies included in the current analysis.

<table>
<thead>
<tr>
<th>Study</th>
<th>Intervals</th>
<th>VO2peak Pre (±SD)</th>
<th>VO2peak Post (±SD)*</th>
<th>Delta (±SD)</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boyd (2013)</strong></td>
<td>1 min intervals</td>
<td>35.4 (5.4)</td>
<td>44.7 (5.0)*</td>
<td>9.4 (3.1)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>100% of WRpeak</td>
<td>2365 (598)</td>
<td>2034 (532)*</td>
<td>-331 (123)</td>
<td>4</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>3x/week for 3 weeks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ma (2013)</strong></td>
<td>20 sec intervals</td>
<td>39.7 (3.0)</td>
<td>47.2 (2.9)*</td>
<td>7.5 (3.2)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>170% WRpeak</td>
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<td></td>
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<td></td>
<td>4x/week for 4 weeks</td>
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<td></td>
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<td></td>
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<tr>
<td><strong>Scribbans (2014a)</strong></td>
<td>20 sec intervals</td>
<td>48.3 (6.1)</td>
<td>54.9 (6.2)*</td>
<td>6.5 (2.5)</td>
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<td>0</td>
</tr>
<tr>
<td></td>
<td>170% WRpeak</td>
<td>2215 (210)</td>
<td>1881 (173)*</td>
<td>-334 (82)</td>
<td>4</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>4x/week for 6 weeks</td>
<td></td>
<td></td>
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<tr>
<td><strong>Scribbans (2014b)</strong></td>
<td>20 sec intervals</td>
<td>50.4 (5.0)</td>
<td>53.3 (5.4)*</td>
<td>3.0 (3.3)</td>
<td>4</td>
<td>31</td>
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<td></td>
<td>170% WRpeak</td>
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<td><strong>Zelt (2014)</strong></td>
<td>30 sec intervals</td>
<td>49.8 (7.8)</td>
<td>51.5 (8.1)</td>
<td>1.71 (3.9)</td>
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<tr>
<td></td>
<td>All-out intensity</td>
<td>198 (30)</td>
<td>221 (32)*</td>
<td>23 (26)</td>
<td>3</td>
<td>30</td>
</tr>
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<td></td>
<td>3x/week for 4 weeks</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>30 sec intervals</td>
<td>44.2 (8.7)</td>
<td>47.1 (7.6)*</td>
<td>3.0 (4.4)</td>
<td>4</td>
<td>30</td>
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<tr>
<td></td>
<td>All-out intensity</td>
<td>200 (35)</td>
<td>215 (32)</td>
<td>15 (29)</td>
<td>8</td>
<td>67</td>
</tr>
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<td>3x/week for 4 weeks</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td>VO2peak</td>
<td>46.1 (8.4)</td>
<td>50.5 (7.4)</td>
<td>4.4 (4.4)</td>
<td>14</td>
<td>22</td>
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<tr>
<td></td>
<td>TTC</td>
<td>2280 (443)</td>
<td>1945 (396)</td>
<td>-334 (100)</td>
<td>8</td>
<td>44</td>
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<tr>
<td></td>
<td>LT</td>
<td>199 (32)</td>
<td>217 (31)</td>
<td>19 (27)</td>
<td>11</td>
<td>55</td>
</tr>
</tbody>
</table>

Values are presented as Mean (±SD). VO2peak (mL/kg/min); TTC, time to completion (seconds); LT, lactate threshold (watts); N, number of non/adverse responders; %, the proportion of non/adverse responders from each participant pool.

* Significant (p>0.05) effect of training within group.
Figure Captions

Figure 1. Individual participant responses to SIT from all studies are shown (A) with 2x the TE illustrated using dashed lines. Non-responders have a VO₂peak response that falls within 2x the TE (shaded region), while adverse responders (checkered bars) have a decrease in VO₂peak greater than 2x the TE. The relationships between individual changes in VO₂peak and 500 kcal TTC (B; Boyd [2013] open circles; Scribbans [2014a] closed circles) or lactate threshold (C; 30 second intervals open circles; 15 second intervals closed circles) are also shown. Dashed lines on panel B and C represent the typical error, while an individual falling within the shaded area would have demonstrated a non-response for both variables.

Figure 2. Individual incidence of response for VO₂peak and TTC are also shown with non-responders (grey).

Figure 3. Individual incidence of response for VO₂peak and lactate threshold are also shown with non-responders (grey), adverse responders (checkered) and overall non-responders (black).
Figure 1

A

Individual Participant Responses

ΔVO_{2peak} (mL/kg/min)

B

Δ Time to Completion (sec)

ΔVO_{2peak} (mL/kg/min)

C

Δ Lactate Threshold (watts)

ΔVO_{2peak} (mL/kg/min)
<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>VO_{2}\text{peak}</strong></td>
<td></td>
<td></td>
<td>0 (0%)</td>
</tr>
<tr>
<td><strong>TTC</strong></td>
<td></td>
<td></td>
<td>8 (44%)</td>
</tr>
<tr>
<td><strong>OVERALL</strong></td>
<td></td>
<td></td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Lactate Threshold</td>
<td>Overall</td>
<td>30-second intervals</td>
<td>15-second intervals</td>
</tr>
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<tr>
<td>V̇O₂peak (%)</td>
<td>9% (41%)</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>11 12 13 14 15 16 17 18 19 20 21 22</td>
</tr>
<tr>
<td>Lactate Threshold</td>
<td>11% (50%)</td>
<td>5 (23%)</td>
<td>9 (41%)</td>
</tr>
</tbody>
</table>