Aerobic Capacity Testing With Inactive Individuals: The Role of Subjective Experience

Renee E. Magnan, Bethany M. Kwan, Joseph T. Ciccolo, Burke Gurney, Christine M. Mermier, and Angela D. Bryan

Background: Maximal oxygen uptake (VO2max), an assessment of cardiorespiratory fitness, is regularly used as the primary outcome in exercise interventions. Many criteria have been suggested for validating such tests—most commonly, a plateau in oxygen consumption. The current study investigated the proportion of inactive individuals who reached a plateau in oxygen uptake and who achieved a valid test as assessed by secondary criteria (RERmax ≥ 1.1; RPEmax ≥ 18; age predicted HRmax ±10bpm), and the correlates of a successful plateau or achievement of secondary criteria during a VO2max session. Methods: Participants (n = 240) were inactive individuals who completed VO2max assessments using an incremental treadmill test. We explored physical, behavioral, and motivational factors as predictors of meeting criteria for meeting a valid test. Results: Approximately 59% of the sample achieved plateau using absolute (increase of VO2 of 150ml O2 or less) and 37% achieved plateau using relative (increase of VO2 of 1.5ml/kg O2 or less) criteria. Being male, having a higher BMI, a greater waist-to-hip ratio, and increased self-efficacy were associated with lower odds of achieving an absolute plateau, whereas none of these factors predicted odds of achieving relative plateau. Conclusion: Findings raise questions about the validity of commonly used criteria with less active populations.

Keywords: VO2max, plateau, sedentary, fitness, criteria

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work by Noakes for alternative interpretations.\textsuperscript{9,10} To reach such a point requires that an individual be both willing and able to push themselves to cardiovascular failure, and thus, many of these tests terminate prematurely and do not result in a valid test. In short, the subjective experiences of the individual (ie, perceived exertion and effort) are key limiting factors.\textsuperscript{10,14,15} Evidence for this argument comes from the procedures involved for conducting graded maximal tests. Although the increase in effort is not under the individual’s control, one point at which maximum is said to have been achieved is when the individual taking the test makes the decision to stop.\textsuperscript{2,9,10}

There is general agreement that not all individuals will reach plateau during an incremental exercise test, and thus a range of secondary criteria have been established to determine whether a “valid” VO$_{2}$max test has been conducted. As with defining plateau, these secondary criteria vary across studies\textsuperscript{3} and there is no definitive agreement on which criteria to use. Typically these criteria include reaching specific levels of rating of perceived exertion (RPE), respiratory exchange ratio (RER), age predicted maximum heart rate (HR), and blood lactate, among others. Although these secondary criteria have been established to enhance the validity of these assessments, the extent to which these secondary criteria are associated with VO$_{2}$max is not well validated, and the existence of these criteria do not change the fact that many tests still terminate prematurely and thus are not tests of VO$_{2}$max at all, but rather tests of VO$_{2}$peak (peak level of VO$_{2}$ without reaching max).

\textbf{VO$_{2}$max Testing Among Inactive Samples}

The tendency to measure VO$_{2}$peak instead of VO$_{2}$max may be particularly relevant for studies utilizing high-risk, less active, or sedentary samples. These individuals are likely unaccustomed to sustaining intense exercise long enough to reach their maximum capacity. Thus, one’s subjective experience during the task is of potentially greater importance among sedentary or less active individuals because their subjective perceptions of physical limits are often lower than their true physiological limits.\textsuperscript{16,17} For example, increases in blood lactate have an earlier onset in sedentary individuals,\textsuperscript{18} and blood lactate and ratings of perceived exertion are strongly related,\textsuperscript{19} thus the likelihood of sedentary individuals to exercise to a level resulting in plateau is low. Others have argued that plateau is less likely to be reached in the less active because they are less willing and or able to perform the test to exhaustion,\textsuperscript{20} further highlighting the role that subjective experience may have on maximal exercise assessments. As a result, sedentary individuals likely reach perceived maximal exertion before they actually reach their true maximal VO$_{2}$max. Indeed, Sidney and Shephard\textsuperscript{21} found that in an elderly sample, individuals who did not reach VO$_{2}$ plateau could be identified based on their motivation to successfully complete the task.

\textbf{Identifying Factors to Increase the Likelihood of Valid VO$_{2}$max Assessment}

If one’s subjective experience, particularly perceived exertion, is key to the attainment of a valid maximal output assessment, then it is possible that certain behavioral, physical, and motivational factors may contribute to enhancing the likelihood of a valid test. For example, individuals who are heavier may find exercising more difficult and therefore experience higher perceived exertion at lower levels of intensity. Individuals who are currently inactive and have had little experience being physically active in the past may not understand the level of physical intensity required for a VO$_{2}$ assessment nor the level of physical intensity of which they are capable, and thus, quit prematurely. In addition, even if a person finds the test challenging, a lack of motivation to work beyond the discomfort of the test may decrease the likelihood of a valid assessment.

A more detailed understanding of the individual differences that are associated with a valid VO$_{2}$max test has the potential to elucidate the limitations of this type of testing with inactive individuals, and potentially suggest ways to modify the test for populations unfamiliar with or unable to push themselves to the maximal limit of their cardiorespiratory fitness. For example, if greater self-efficacy toward exercise (ie, confidence in one’s abilities to exercise) increases the likelihood of meeting validation criteria, then a researcher might consider having participants engage in a practice session as a way to increase self-efficacy toward exercise (and thereby increase motivation) before completing the fitness test.

\textbf{Cardiovascular Fitness in Physical Activity Interventions}

From a health promotion perspective, understanding the assessment of cardiorespiratory fitness in less active populations (as opposed to trained athletes as is common in the literature)\textsuperscript{22–25} who are seeking to increase exercise participation or increase overall health is particularly important because it is often used as a means to develop guidelines for exercise prescription and/or is used as the primary outcome to quantify cardiovascular fitness before and after an intervention.\textsuperscript{1} The first issue is important in that if a valid measurement of VO$_{2}$max cannot be obtained, then the fitness prescription for that person is inherently biased and may not be sufficient to meet fitness goals. The second issue relates to the interpretation of intervention outcome data as well as the comparison of data across studies. Many exercise treatment programs include cardiovascular fitness as an outcome, and the effectiveness of various types of interventions at increasing fitness is compared across studies (using absolute VO$_{2}$max).\textsuperscript{2} If researchers cannot adequately assess fitness before an intervention, then the final fitness assessment

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is less informative. Specifically, it is difficult to know if any changes are due to a change in fitness (because of the exercise treatment) or due to participants becoming better at and more motivated to perform during the fitness assessment. With regard to measurement issues per se, if studies use various combinations of secondary criteria to assess VO2max, it becomes increasingly difficult to make direct comparisons from study to study. Thus, it is important to better understand the factors that may contribute to elongating these tests, particularly regarding the role that subjective experiences such as perceived exertion and motivation play.

Objectives

This paper is an investigation of VO2max testing among inactive healthy individuals. We focused on the proportion of individuals who achieved a valid plateau in VO2 as an indicator of reaching VO2max, and also investigated the proportion of individuals who reached a valid VO2max as assessed by secondary criteria outlined by Pimentel and colleagues (eg, RERmax ≥ 1.1; RPEmax ≥ 18; age predicted HRmax ±10bpm). We explored several potential correlates of achieving a valid VO2max in less active individuals including physical [age, gender, Body Mass Index (BMI), wait-to-hip ratio (WHR)], behavioral (total minutes of at least moderate-intensity physical activity over the past week, ever a regular exerciser), and self-efficacy toward exercise (a motivational factor outlined by the Theory of Planned Behavior). We hypothesized that men, younger adults, individuals with a smaller BMI and WHR, those who are currently more active, and have regularly exercised in the past, and who have greater self-efficacy toward exercise would be more likely to reach plateau (absolute and relative) during the VO2max assessment. Although we did not specifically hypothesize relationships regarding the secondary criteria, it is informative to understand both the relationship between achieving a valid plateau and the secondary criteria, as well as the potential disparity in factors that predict plateau versus the secondary criteria.

Methods

Participants and Design

Participants were 240 inactive, but otherwise healthy, individuals (197 women and 43 men) who were seeking enrollment into a larger exercise intervention study (COSTRIDE). Three hundred and thirty-eight individuals were recruited for COSTRIDE; the current analysis included all individuals who met eligibility criteria and completed a fitness assessment. Individuals were excluded if they smoked cigarettes, were on a restricted diet, taking psychotropic medications, receiving treatment for any psychiatric disorder, diabetic, had a history of cardiovascular or respiratory disease, had the flu or illness in the previous month, or were pregnant (if female). After giving written informed consent, participants provided demographic information and completed a VO2max test. For the purposes of this analysis, we defined inactive as 90 or fewer minutes of voluntary exercise in the previous 7 days. Participants were recruited through advertisements in the Denver-metro and University of Colorado (CU) communities to participate in a 12-month randomized controlled trial testing an intervention to increase exercise behavior. Only participants who passed a general physical administered by a study physician were eligible to participate. The data collected herein were gathered before random assignment to condition. Procedures were approved by all relevant institutional review boards. Details regarding recruitment, study sample, and procedures of COSTRIDE are provided elsewhere.

VO2max Fitness Test

VO2 was assessed via open-circuit spirometry taking 30-second averages (Medgraphics Cardi02/CP system, St. Paul, MN) during incremental treadmill exercise (Trackmaster 425 treadmill, Newton, KS). Participants warmed up for 2–5 minutes to determine a speed corresponding to 70%–80% of age-predicted maximal heart rate. Participants ran/walked at this speed, while the grade increased by 2.0% (or increased by 2.5% if the speed was ≥ 6.0mph) every 2 minutes until volitional exhaustion. At the end of each grade increase, 1 RPE rating and 2 HR measurements (averaged to create 1 HR score for each challenge level) were taken. The Borg scale assessed RPE. Participants gave a hand signal to indicate if they were considering ending the test. At this time encouragement was given to facilitate reaching plateau. However, the test was stopped when the participant indicated that he or she could not continue.

Plateau was defined in 2 ways. In response to an increase in speed or incline of the treadmill, absolute plateau was defined as a maximal increase of absolute VO2 of 150ml O2 or less and relative plateau was defined as VO2 of 1.5ml/kg O2 or less. Following previously published procedures with sedentary individuals, participants’ data were coded for having met the criteria for achieving a valid VO2max assessment: 1) plateau in oxygen uptake with increased workload; 2) RERmax ≥ 1.1; 3) RPEmax ≥ 18; and 4) reaching age predicted HRmax (±10bpm). We determined what proportion of participants achieved absolute or relative plateau, what proportion of participants met each of the secondary criteria, and what proportion of participants met at least 3 criteria.

Demographics and Individual Difference Measures

Participants indicated their age, gender, and ethnicity. Height and weight for BMI calculations, measurement of waist and hip for calculating waist-to-hip ratio, and resting heart rate measurements were taken before the exercise test. Minutes and intensity of voluntary aerobic
exercise over the previous 7 days was determined by the 7-Day Self-Report Physical Activity Recall (PAR), an interview assessment widely used in exercise research. Past experience with consistent exercise was assessed by 1 question asking participants to indicate if they had ever exercised regularly for 6 months or more and then stopped for 3 or more months. Finally, self-efficacy toward exercise was measured with 9 items. Participants rated their confidence in their abilities to engage in aerobic activity ($\alpha = .87$).

### Statistical Analysis

We used simple logistic regression in SPSS 16.0 to determine odds ratios for meeting criteria, with each physical, behavioral, and motivational variable alone predicting each criterion.

### Results

#### Sample Characteristics

Participants were 28.16 years of age (SD = 8.08, range: 18–45) and the majority were White/Caucasian (68.6%). Average BMI was 25.16 (SD = 4.79) with 45.6% considered overweight or obese. There were no gender differences in BMI. Average WHR was .77 (SD = .07), and men (mean = .83, SD = .06) had significantly larger WHRs than women (mean = .76, SD = .06), $t(229) = 7.04, P < .001$; although men typically have higher WHRs than women. Average VO$_2$ max was 33.69 ml/kg/min (SD = 7.62), and men (mean = 42.24, SD = 7.68) had significantly higher VO$_2$ max than women (mean = 31.82, SD = 6.21), $t(228) = 9.53, P < .001$. Participants reported engaging in an average of 17.37 minutes of voluntary aerobic exercise of at least moderate intensity in the past week (SD = 26.21; range: 0–90 min.) although the mode was zero minutes. As minutes of voluntary exercise were highly skewed, they were log transformed before further analysis.

#### Achieving a Valid VO$_2$ max Assessment

Absolute plateau was achieved by 59.0% of the sample, 37.1% achieved relative plateau, 67.5%, achieved a RERmax $\geq 1.1$, 93.7% achieved a RPEmax $\geq 18$, and 84.6% achieved age-predicted HRmax (±10bpm). Altogether, 75.4% met at least 3 criteria for a valid VO$_2$ max test using absolute plateau and 69.6% met at least 3 criteria for a valid VO$_2$ max test using relative plateau. Figure 1 displays the proportion of individuals who met each criterion. Although all participants ended the test when they reached volitional exhaustion (ie, reported they could go no further), more than half reached an absolute plateau in VO$_2$ while far fewer reached a relative plateau. Further, nearly three-quarters reached at least 3 of 4 criteria for a valid VO$_2$ max test (defined as either absolute or relative). Table 1 presents the individual difference means and standard deviations between individuals who reached plateau and those who met at least 3 of the 4 criteria.

![Figure 1](image_url) — Proportion of individuals who met each VO$_2$ max validation criterion. Note. Absolute plateau refers to VO$_2$ change meeting 150ml O$_2$ or less. Relative plateau refers to VO$_2$ change meeting 1.5ml/kg O$_2$ or less. Ns refer to number of participants who achieved each criterion.
Table 1 Means and Standard Deviations of Predictor Factors of Each VO2max Validation Criterion

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Absolute plateau (n = 141)</th>
<th>Relative plateau (n = 89)</th>
<th>3+ criteria absolute (n = 181)</th>
<th>3+ criteria relative (n = 167)</th>
<th>Total (n = 240)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>27.44 (8.09)</td>
<td>29.06 (7.95)</td>
<td>28.28 (8.09)</td>
<td>28.62 (8.05)</td>
<td>28.16 (8.08)</td>
</tr>
<tr>
<td>% female</td>
<td>87.9</td>
<td>85.4</td>
<td>82.9</td>
<td>83.2</td>
<td>82.1</td>
</tr>
<tr>
<td>BMI</td>
<td>24.35 (4.51)</td>
<td>25.08 (4.53)</td>
<td>24.94 (4.60)</td>
<td>25.07 (4.61)</td>
<td>25.16 (4.79)</td>
</tr>
<tr>
<td>WHR</td>
<td>.758 (.07)</td>
<td>.762 (.07)</td>
<td>.765 (.07)</td>
<td>.765 (.07)</td>
<td>.770 (.07)</td>
</tr>
<tr>
<td>Self-efficacy (1-7)</td>
<td>4.73 (1.13)</td>
<td>4.71 (1.12)</td>
<td>4.82 (1.08)</td>
<td>4.91 (1.08)</td>
<td>4.86 (1.10)</td>
</tr>
<tr>
<td>PA voluntary minutes</td>
<td>17.87 (25.34)</td>
<td>19.26 (27.11)</td>
<td>18.35 (26.60)</td>
<td>18.69 (26.89)</td>
<td>17.37 (26.18)</td>
</tr>
<tr>
<td>% ever exercise</td>
<td>60.7</td>
<td>63.6</td>
<td>67.8</td>
<td>69.3</td>
<td>65.7</td>
</tr>
<tr>
<td>VO2max (ml/kg/min)</td>
<td>33.54 (7.13)</td>
<td>33.42 (7.37)</td>
<td>33.86 (7.39)</td>
<td>33.81 (7.42)</td>
<td>33.69 (7.62)</td>
</tr>
</tbody>
</table>

**Predictors of Achieving a Valid VO2max Assessment**

Table 2 presents the odds ratios and 95% confidence intervals around the odds ratio of meeting each criterion. There was no association of age with achieving absolute plateau. Male participants were significantly less likely to achieve absolute plateau than female participants (P = .003). Higher BMI (P = .002) and higher WHR (P = .001) were associated with lower odds of achieving absolute plateau; these effects were unchanged when controlling for gender. Greater exercise self-efficacy was associated with lower odds of achieving absolute plateau (P = .03), and a history of regular physical activity in the past just missed the conventional cutoff for significance (P = .055). Being inactive in the past was associated with greater odds of reaching absolute plateau. None of the predictors were significantly associated with odds of achieving relative plateau.

Greater age was the only factor significantly associated with greater odds of achieving RER ≥ 1.1 (P = .006). A history of regular physical activity was the only variable significantly associated with greater odds of achieving age-predicted HRmax within 10bpm (P = .02), although self-efficacy was marginally associated (P = .06) with greater odds. None of the factors tested were associated with odds of achieving RPE ≥ 18 although this is likely due to the extremely small amount of variance of individuals who reached the RPE criterion (94%).

Finally, a smaller WHR was associated with greater odds of meeting at least 3 criteria using absolute plateau (P = .04). None of the predictors were significantly associated with odds of achieving 3 criteria using relative plateau.

**Discussion**

The current study investigated the proportion of inactive individuals who reached a plateau in VO2max and those who reached a valid VO2max based on meeting 3 of 4 criteria. Over half of the participants reached absolute VO2 plateau (59.0%) while far fewer reached relative VO2 plateau (37.1%). Regardless of whether plateau was defined in absolute or relative terms, a large proportion of the sample did not reach a discernable plateau. When other criteria were considered, however, the percentage of individuals who achieved a valid test increased dramatically. Approximately 16% more participants achieved a valid VO2max test when the secondary criteria were used than when absolute plateau was the sole criterion, and an additional 32.5% more participants achieved a valid VO2max test when the secondary criteria were used as compared with when relative plateau was the sole criterion. Clearly, the decision to use specific criteria (eg, relative versus absolute change in VO2, secondary criteria) to determine the validity of a VO2max test greatly influences the percentage of participants who achieve a valid test. These differences in achievement rates highlight the need to understand the factors that may account for the discrepancies in reaching the individual criteria to enhance the validity of these tests.

Using this line of reasoning, we also investigated factors that may predict successful attainment of VO2 plateau and criteria for a valid assessment of a VO2max test. Consistent with our hypotheses, greater BMI and greater WHR were associated with lower odds of achieving an absolute plateau in VO2. In contrast to our hypotheses, male gender, greater exercise self-efficacy, and being physically active in the past were all associated with lower odds of achieving an absolute plateau in VO2, whereas there was no effect of age or amount of current aerobic activity. In addition, none of the factors predicted odds of attaining a relative plateau in VO2. Only decreased WHR predicted odds of achieving a valid VO2max test by meeting at least 3 criteria using absolute plateau. Thus, in terms of absolute plateau, we found evidence of behavioral, physical, and motivational factors contributing to the valid attainment of VO2max.

Consistent with previous research is the relationship between weight (represented in the current study by BMI and WHR) and VO2max attainment. Weight may very well play a role in whether an individual is physically...
### Table 2  Odds Ratios (OR) and 95% Confidence Intervals (CI) for Meeting Each Criterion

<table>
<thead>
<tr>
<th></th>
<th>Absolute plateau</th>
<th>Relative plateau</th>
<th>RER ≥ 1.1</th>
<th>HR_{	ext{max}} ±10</th>
<th>3+ criteria (absolute)</th>
<th>3+ criteria (relative)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OR</strong></td>
<td><strong>95% CI</strong></td>
<td><strong>OR</strong></td>
<td><strong>95% CI</strong></td>
<td><strong>OR</strong></td>
<td><strong>95% CI</strong></td>
<td><strong>OR</strong></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>.98</td>
<td>.94–1.01</td>
<td>1.00</td>
<td>.97–1.03</td>
<td><strong>1.05</strong></td>
<td><strong>1.02–1.09</strong></td>
</tr>
<tr>
<td><strong>Gender (M = 1, F = 0)</strong></td>
<td>.38</td>
<td><strong>.19–.74</strong></td>
<td>.69</td>
<td>.34–1.41</td>
<td>1.14</td>
<td>.56–2.32</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>.92</td>
<td><strong>.87–.97</strong></td>
<td>1.00</td>
<td>.94–1.05</td>
<td>1.03</td>
<td>.97–1.09</td>
</tr>
<tr>
<td><strong>WHR</strong></td>
<td><strong>.002</strong></td>
<td><strong>.00–.09</strong></td>
<td>.09</td>
<td>.00–4.70</td>
<td>1.96</td>
<td>.04–97.98</td>
</tr>
<tr>
<td><strong>PA voluntary min</strong></td>
<td>1.08</td>
<td>.94–1.25</td>
<td>1.08</td>
<td>.93–1.25</td>
<td>1.00</td>
<td>.86–1.16</td>
</tr>
<tr>
<td><strong>Ever exercise</strong></td>
<td>.59</td>
<td><strong>.33–1.03</strong></td>
<td>.87</td>
<td>.50–1.50</td>
<td>1.02</td>
<td>.58–1.80</td>
</tr>
<tr>
<td><strong>Self-efficacy</strong></td>
<td><strong>.77</strong></td>
<td><strong>.60–.98</strong></td>
<td><strong>.82</strong></td>
<td><strong>.64–1.04</strong></td>
<td>.98</td>
<td>.76–1.25</td>
</tr>
</tbody>
</table>

* P < .05; ** P < .01; *** P < .001; † P < .10.

Note. Due to the low variance of individuals reaching RPE ≥ 18 and the resulting lack of predictors, RPE was not included in this table.
able to continue working long and hard enough to reach plateau, and also may play a role in how difficult working to maximum effort is perceived. Thus, it is tempting to attribute the lack of effects on relative plateau to the fact that relative plateau accounts for weight. However, in the current study, with the exception of BMI ($r = .31$, $P < .001$), weight (kg) was only weakly associated with the behavioral, physical, and motivational factors we tested ($r_s: .03-.15$), and when weight was included as a covariate in these analyses, the relationships between these factors and plateau attainment (absolute or relative) were unchanged. Nonetheless, given the relationship between BMI and WHR to absolute plateau, researchers should be mindful of the use of this assessment in obese or overweight samples.

The relationship between plateau rates and gender is inconsistent with previous literature typically showing that males are more likely to reach a VO$_2$ plateau than females.$^{35}$ In the current study, males reported more moderate or greater intensity exercise (24.77 minutes) in the past week than females (15.76 minutes); however, far fewer males (20.9%) than females (79.1%) reported a history of being physically active in the past. Thus, it is tempting to attribute the relationship of gender to reaching absolute plateau to being physically inactive in the past. However, a history of inactivity was marginally associated with greater likelihood of reaching absolute plateau, and current activity during the past 7 days did not predict any criteria. Thus, being previously or currently physically active does not necessarily guarantee that an individual will reach a plateau VO$_2$ level during a fitness test. In other words, amount of physical activity is not always equivalent to physical fitness.$^{39}$ Nevertheless, one should be mindful that less active men and less active women may perform differently during VO$_2$max testing.

A counterintuitive finding was that aerobic exercise self-efficacy was inversely related to achieving plateau. We had expected that individuals who were more confident in their abilities to do aerobic activity would perform better. In contrast, we found that people who had less confidence in their abilities to exercise were more likely to achieve a definitive absolute plateau during the fitness test. Self-efficacy should be more predictive of behavior when it is framed for a specific outcome.$^{40}$ Thus, self-efficacy might have been a better predictor if confidence in completing the VO$_2$max test was assessed rather than confidence in exercising more generally. Bearing in mind that this was a currently sedentary sample, it is also possible that individuals who reported higher self-efficacy may be confident in their ability to perform activities at a lower than moderate intensity (rather than a moderate or higher intensity), and this confidence simply did not translate to an increased ability to work to exhaustion during a maximal test—a test in which they are unlikely to have engaged in the past. Indeed this is anecdotally consistent with our PAR interviews, in which some participants reported leisurely walking with their pet or carrying a laundry basket as part of their voluntary moderate-intensity physical activity. While these activities could be performed at a moderate-level, when our trained interviewers probed for additional information regarding HR and perceived exertion, it was often found that what participants reported as “moderate intensity” was actually light intensity. This finding is consistent with research demonstrating that sedentary individuals overestimate the intensity of their physical activity.$^{51}$ Ultimately, these individuals may have misperceptions based on their previous successful experience with lower intensity physical activity resulting in higher self-efficacy toward aerobic exercise, but reduced odds of achieving a plateau since the intensity is considerably higher than their typical experience.

Achieving maximal exertion is a subjective experience; individuals typically stop the test when they perceive they can no longer continue, not when they reach some physiological indicator. Therefore, it is one’s subjective experience during the test that is central to a valid VO$_2$max assessment. In fact, the test assumes one’s RPE and VO$_2$max levels are related since Borg’s RPE scale was originally constructed as a subjective measure of intensity among healthy individuals that would map on to heart rate during exercise.$^{30,42}$ and ultimately determines the termination of the test. However, it has clearly been shown that RPE is less related to VO$_2$ and HR in less active or sedentary individuals$^{23,24}$ the target population for this study. Therefore, it is not surprising that in this study, although RPE and VO$_2$max levels were significantly associated, albeit weakly, ($r = -.16$, $P = .03$), that the rate of achieving absolute or relative plateau was unrelated to achieving RPE$_{max}$ $\geq 18$ ($r = -.04$ and $r = -.05$, respectively). Statistically, these weak relationships are likely due to a lack of variance given that nearly the entire sample reached an RPE of 18 or higher. From a practical standpoint, 94% of the sample reported perceiving that they had reached their physiological limits although in many cases they clearly had not. Again, the idea that sedentary or less active individuals may be less accurate at perceiving their physiological limits is consistent with previous work with this population.$^{16,17}$ Another practical implication is that it is possible that participants were not willing to work to their physiological limits and therefore simply reported a higher RPE than they were actually experiencing. However, this possibility is somewhat lessened due to the relatively high percentage of participants who met the physiological criteria for respiratory exchange ratio and maximal heart rate. Whether the weak relationship between plateau and maximum RPE is due to participants believing that they had reached their limit or that they were simply unwilling to work to their limit, enhancing motivation may be important for increasing the likelihood that participants reach their actual VO$_2$max.

Importantly, none of the secondary criteria used in the current study were associated with the likelihood of reaching absolute plateau (RER $1.1 = -.09$ and HR$_{max}$ $= -.07$) or relative plateau (RER$1.1 = -.04$ and HR$_{max}$ $= .02$). Given these relationships, it is not entirely surprising that factors predicting plateau rates did not predict rates of
achieving the secondary criteria. These findings highlight the complexity of determining a valid VO\(_2\)max test among less active individuals, and reinforce that research in this area is important given that the commonly used secondary criteria simply do not strongly relate to actual plateau.

One criticism of these data may be that the protocol for assessing VO\(_2\)max may not have been appropriate for use with the current population. Howley et al\(^3\) suggest that there are groups for whom a plateau is less likely to occur during continuous incremental tests: low-fit, children, and elderly. A protocol with modifications may be more appropriate for a less fit and less active population. For example, some commonly used protocols (eg, Bruce Treadmill Protocol, Balke-Ware Treadmill Protocol) have modifications to ease participants into the procedures.\(^1\) Additionally, an argument could be made that the participants were not pushed to work to maximal effort, resulting in the test being terminated prematurely. However, the rates of achieving plateau in the current study are likely not due to a lack of effort as the vast majority of individuals reached their perceived maximal exertion, and the rates of achieving other criteria were also quite high. Another limitation to this work is that we were not able to compare an inactive sample with an active sample and therefore investigate current activity status as a moderator of the effects tested here. Such tests would provide greater evidence that certain behavioral, physical, and psychological factors would aid improvement of maximal assessments specifically in inactive populations.

**Conclusions**

This was an investigation of aerobic capacity testing in less active individuals. These data highlight the importance of taking into account subjective experiences (ie, perceived exertion) when developing protocols and criteria for determining valid VO\(_2\)max assessments particularly among less fit and less active individuals. These data further suggest that when working with less active and less fit populations, researchers need to consider factors that may influence the outcome of a valid VO\(_2\)max test. This issue is clinically relevant as VO\(_2\)max is often used as an objective measure to evaluate the effectiveness of interventions designed to increase physical activity. Although our work provides no firm conclusions regarding these issues, it highlights the crucial need for additional investigations of the plateau phenomenon, and the role of subjective experiences in VO\(_2\)max testing among less fit and inactive individuals.

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