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Review

Physiological attributes of triathletes

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Abstract

Triathlons of all distances can be considered endurance events and consist of the individual disciplines of swimming, cycling and running which are generally completed in this sequential order. While it is expected that elite triathletes would possess high values for submaximal and maximal measures of aerobic fitness, little is known about how these values compare with those of single-sport endurance athletes. Earlier reviews, conducted in the 1980s, concluded that triathletes possessed lower $V_{O_2 max}$ values than other endurance athletes. An update of comparisons is of interest to determine if the physiological capacities of elite triathletes now reflect those of single-sport athletes or whether these physiological capacities are compromised by the requirement to cross-train for three different disciplines. It was found that although differences in the physiological attributes during swimming, cycling and running are evident among triathletes, those who compete at an international level possess $V_{O_2 max}$ values that are indicative of success in endurance-based individual sports. Furthermore, various physiological parameters at submaximal workloads have been used to describe the capacities of these athletes. Only a few studies have reported the lactate threshold among triathletes with the majority of studies reporting the ventilatory threshold. Although observed differences among triathletes for both these submaximal measures are complicated by the various methods used to determine them, the reported values for triathletes are similar to those for trained cyclists and runners. Thus, from the limited data available, it appears that triathletes are able to obtain similar physiological values as single-sport athletes despite dividing their training time among three disciplines.

Keywords: Triathlon; Bicycling; Exercise test; Physical endurance; Running

Contents

1. Physiological attributes of triathletes

Triathlon is an event comprising the individual disciplines of swimming, cycling and running and is generally completed in this sequential order. Although race distances vary, triathlons of all distances can be considered to be endurance events. The most common measure of aerobic fitness is maximal oxygen consumption ($\dot{V}_{O_2 max}$) and this has often been proposed as a determinant of endurance success.[1] However, physiological measurements at submaximal workloads have also been shown to be important determinants of endurance performance.[2,3] Thus, while it is expected that elite triathletes would possess high values for submaximal and maximal

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measures of aerobic fitness, little is known about how these values compare with those of single-sport endurance athletes. Such comparisons are of interest to determine if the physiological capacities of triathletes reflect those of single-sport athletes or whether theses physiological capacities are compromised by the requirement to cross-train for three different disciplines; this has obvious implications for the training of triathletes.

Although there have been previously published reviews on the physiological attributes of triathletes,[4,5] these were all published at least 12 yrs prior to the current review. Since these reviews, the sport of triathlon has increased its professionalism and triathletes are more likely to enter the sport as triathletes (with a training background in all three disciplines), rather than being converted from one of the individual sports that comprise a triathlon. Thus, an updated review is required that investigates the physiological attributes of contemporary triathletes and compares this with single-sport athletes. Unlike previous reviews, prior to making such comparisons we will first justify the physiological measures chosen and briefly comment on the use of absolute or relative measures of aerobic fitness. In addition, while previous reviews have concentrated on comparisons of $\dot{V}_{O_2\,max}$ (and sometimes economy), this paper provides an expanded review of the physiological attributes of triathletes and includes measures such as the lactate threshold (LT), the ventilatory threshold (VT) and peak power and velocity.

2. Maximal measures

Successful endurance athletes are characterised by high levels of aerobic power (as measured by $\dot{V}_{O_2\,max}$), which are nearly double that of the untrained individual, and this has often been cited as an important predictor of endurance success among athletes heterogenous for aerobic power.[2,6,7] There are different methods of normalising $\dot{V}_{O_2\,max}$ measures, such as per unit of fat free mass or lower-leg volume.[8] Most commonly however, $\dot{V}_{O_2\,max}$ is expressed in absolute values ($L\,min^{-1}$) or relative to body mass ($mL\,kg^{-1}\,min^{-1}$). As the three events that comprise a triathlon differ in the amount of body mass that must be supported by the athletes and, therefore, in the energy required to maintain body position, different methods for normalising $\dot{V}_{O_2\,max}$ may be required for the different triathlon disciplines.

Although studies have demonstrated that absolute $\dot{V}_{O_2\,max}$ is associated with swimming performance over a distance of 400 m,[9,10] Costill et al.[11] found that relative $\dot{V}_{O_2\,max}$ was more highly correlated ($r = 0.74$ vs. 0.47) with swimming performance over a similar (365.8 m) distance. Furthermore, one study has reported a poor correlation ($r = 0.30$) between absolute $\dot{V}_{O_2\,max}$ and 400-m swim performance.[12] These results are despite similar absolute $\dot{V}_{O_2\,max}$ values between the studies. Therefore, while absolute $\dot{V}_{O_2\,max}$ is more commonly reported among swimmers, relative $\dot{V}_{O_2\,max}$ may be more appropriate when reporting and comparing the $\dot{V}_{O_2\,max}$ of swimmers and triathletes. Indeed, Sleivert and Wenger[13] reported that relative and not absolute $\dot{V}_{O_2\,max}$ was significantly related to swim performance during a triathlon. The analysis of $\dot{V}_{O_2\,max}$ values in triathletes is also complicated by the observation that, when compared to cycling and running, swimming requires a greater degree of specialist training to elicit high $\dot{V}_{O_2\,max}$ values[14] and receives little cross-training benefits from cycling and running.[15]

During cycling, the entire body mass is supported by the bike and therefore a higher absolute $\dot{V}_{O_2\,max}$ would appear advantageous. However, both absolute and relative $\dot{V}_{O_2\,max}$ values of cyclists have typically been reported,[3,16–18] and the most appropriate measure may depend on the type of cyclist being compared. Professional cyclists who are considered "climbers" have a higher relative $\dot{V}_{O_2\,max}$ (and lower body mass) compared to those considered specialist time trialists (time trials are generally conducted over flat courses) despite similar absolute $\dot{V}_{O_2\,max}$ values.[16]

In contrast to cycling, relative $\dot{V}_{O_2}$ during running is constant among individuals for any given velocity.[19] Although Costill[20] reported a relationship between both absolute and relative $\dot{V}_{O_2\,max}$ and running performance, a stronger relationship was found for relative compared to absolute $\dot{V}_{O_2\,max}$ ($r = 0.83$ and 0.59 respectively). Generally $\dot{V}_{O_2\,max}$ values among runners are reported in relative values[2,21–23] as it is recognised that extra body mass is detrimental to running performance.[24]

As triathletes compete in swimming, cycling and running, $\dot{V}_{O_2\,max}$ has often been reported in both relative and absolute values.[13,24–36] However, from the above discussion, it could be argued that the most appropriate means to compare swimmers and triathletes is using relative $\dot{V}_{O_2\,max}$. Furthermore, as the run leg has often been reported to be an important predictor of triathlon performance,[37] the disadvantage of a large body mass on running performance may also render relative $\dot{V}_{O_2\,max}$ more appropriate when comparing the $\dot{V}_{O_2\,max}$ values of cyclists and triathletes. A further consideration is that the athlete may be able to compensate for a low $\dot{V}_{O_2\,max}$ (either absolute or relative) with higher efficiency or economy values.[38] Therefore, although the most appropriate measure for triathletes has not yet been determined, for the purposes of this review, $\dot{V}_{O_2\,max}$, unless otherwise indicated, will refer to the relative value.

Triathletes generally possess high $\dot{V}_{O_2\,max}$ values. Studies that have reported the $\dot{V}_{O_2\,max}$ of triathletes are summarised in Table 1 (see supplementary files). $\dot{V}_{O_2\,max}$ values reported for triathletes during swimming, cycling and running have ranged from 49.9 to 57.7 $mL\,kg^{-1}\,min^{-1}$, 43.6–75.9 $mL\,kg^{-1}\,min^{-1}$ and 49.7–78.5 $mL\,kg^{-1}\,min^{-1}$ respectively for males, and from 38.1 to 45.3 $mL\,kg^{-1}\,min^{-1}$, 48.2–61.3 $mL\,kg^{-1}\,min^{-1}$ and 50.7–65.6 $mL\,kg^{-1}\,min^{-1}$ respectively for female triathletes.

While triathletes possess high $\dot{V}_{O_2\,max}$ values, it has been suggested, in a review paper, that $\dot{V}_{O_2\,max}$ values among triathletes during swimming, cycling and running are less than that of athletes specialising in only one of these exercise