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Differences in gender and performance in off-road triathlon

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Abstract

The aims of this study were: (1) to examine performance trends and compare elite male and female athletes at the off-road triathlon (1.5-km swim, 30-km mountain biking, and 11-km trail running) world championships since its inception in 1996, and (2) to compare gender-related differences between off-road triathlon and conventional road-based triathlon. Linear regression analyses and ANOVA were used to examine performance trends and differences between the sexes. Elite male performance times stabilized over the 2005–2009 period, whereas elite female performance times continued to improve, especially for the run leg. Differences in performance times between the sexes were less marked in swimming than in mountain biking and running, whereas differences in power output were more marked for mountain biking than for swimming and running. In addition, differences in cycling between the sexes were greater for off-road than conventional on-road triathlon. The specific aspects of mountain biking (e.g. level and terrain) may partly explain the significant differences between the sexes recorded in cycling for off-road triathlon. Future studies will need to focus on the physiological bases of off-road triathlon and how they differ from conventional triathlon.

Keywords: *Swimming, mountain biking, running, differences between the sexes, Xterra®*

Introduction

Off-road triathlon combines swimming, mountain biking, and running and is relatively new in the field of endurance sports. Since 1996, the world's premier off-road triathlon, the Xterra® world championship, has comprised a 1.5-km swim, a 30-km mountain bike ride, and a 11-km trail run, and has taken place on the island of Maui (Hawaii, USA). The Xterra® world championship race is the last in a series of nearly 100 off-road triathlon races held in 12 countries and 32 US States each year. The concept is to provide an off-road triathlon world championship for amateur and elite athletes. For each of the last 5 years, more than 500 racers (25% females) representing 22 countries have taken part in this event; elite male triathletes finish in approximately 2.5 h.

In contrast to conventional (road-based) triathlon, the cycling and running legs of off-road triathlon take place on trails, with frequent significant ascents during the cycling leg of the race. Mountain biking requires specific aerobic and anaerobic capacities and technical abilities that differ considerably from road cycling (Impellizzeri & Marcora, 2007). Similarly, running on trails is specific and also requires more technical ability than road running. Even though the specific aspects of conventional triathlon have already been well investigated (Bentley, Millet, Vleck, & MacNaughton, 2002), to our knowledge no study has looked at aspects of performance in off-road triathlon.

Differences in endurance performance between the sexes have been studied extensively during running (e.g. Coast, Blevins, & Wilson, 2004; Sparkling, O'Donnell, & Snow, 1998) and, to a lesser extent, swimming (e.g. Tanaka & Seals, 1997). For long trail running competitions (e.g. 161 km), Hoffman and Wegelin (2009) showed that the difference in performance time between the sexes decreased during the previous two decades, reaching around 14% in 2007. However, no information is available on shorter trail running races, such as the 11-km running segment of the off-road triathlon. In addition, there is a paucity of data on differences between the sexes in road cycling and mountain biking (Schumacher, Mueller, & Keul, 2001), partly because males and females do not race the same event, making comparisons difficult. Moreover, differences in triathlon have also received little

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attention. Analysis of pacing and distribution of power output during the cycling legs of triathlon world cups for elite male and female competitors has revealed significant differences between the sexes (Bernard et al., 2009; Le Meur et al., 2009; Vleck, Bentley, Millet, & Bürgi, 2008). In particular, Lepers (2008) reported performance time differences between the sexes in swimming, cycling, running, and the three legs combined of 9.8%, 12.7%, 13.3%, and 12.6% respectively for the Ironman distance (3.8-km swim, 180-km cycle, 42-km run). During off-road triathlon, males and females race at the same time, thus providing a good model to examine differences in performance between the sexes because they can be analysed across the three disciplines (i.e. swimming, mountain biking, and trail running) separately and also collectively.

The aims of the present study were therefore twofold: (1) to analyse performance trends and gender-related differences in swimming, mountain biking, running, and overall performance at the Xterra® world championships since its inception in 1996, and (2) to compare gender-related differences between the Xterra® world championship and other conventional triathlon world championships in 2009. Due to the nature of the discipline (i.e. a high anaerobic component), mountain biking requires different physiological aptitudes compared with conventional triathlon cycling. We therefore hypothesized that any differences in cycling between the sexes would be greater for off-road than for conventional road-based triathlon.

Materials and methods

Approval for the project was obtained from the Burgundy University Committee on Human Research. The data set from this study was obtained from the Xterra® website: http://www.xterraplanet.com/maui/past.html and Garmin GPS data. First, we analysed the swimming, mountain biking, running, and overall performance times of the male and female winners of the first event in the Xterra® world championships held from 1996 to 2009. Since 2005, the Xterra® world championship has taken place in October in Makena, Maui (Hawaii, USA) with only minor changes to the course. The championship is a point-to-point race, combining a 1.5-km swim in the ocean, a 30-km mountain bike ride that involves a total altitude change of 915 m, and a 11-km trail run (total altitude change of 346 m) that traverses lava rock, forest trails, and beach sand. As Xterra® only provided complete results (times for each discipline) since 2005, we focused our attention on the 2005–2009 period. Therefore, average swimming, mountain biking, running, and overall performance times of the top 10 males and females at the Xterra® world championships were analysed only during the 2005–2009 period. The average of the top 10 performances provided a more accurate indication of performance change than winning time alone and formed a better index for comparing male and female performances. The magnitude of the differences between the sexes was assessed by calculating the percent difference for the swimming, mountain biking, running, and total performance times of the top 10 males versus top 10 females. The time difference between the winner and the tenth-placed athlete was also analysed and expressed as a percentage of the winning performance for both males and females.

Percent differences in time do not equate to percent differences in power output, because of non-linear relationships between speed and power output from air or water resistance (Hopkins, Schabort & Hawley, 2001). We therefore estimated the percent difference in power output between the males and females for each discipline according to methods described by Lepers (2008). Briefly, for swimming the mechanical power (P) depends on the third power of velocity (V). According to the model proposed by Stefani (2006), the power ratio between males (m) and females (f) is:

$$\textit{Swimming}: P_f/P_m = 0.91\left(V_f/V_m\right)^3$$

Similarly for cycling, the mechanical power also depends on the third power of velocity. Assuming level terrain, no wind, and that the contribution of rolling resistance to total power demand is negligible, the power ratio between males and females is:

$$\textit{Cycling}: P_f/P_m = 0.93\left(V_f/V_m\right)^3$$

For running, the mechanical power depends on the velocity and on body mass (Stefani, 2006). The power ratio between males and females for running is:

$$\textit{Running}: P_f/P_m = 0.79\left(V_f/V_m\right)$$

Finally, in the three disciplines, the percentage difference in power between females and males (%DP) was calculated as follows:

$$\%DP = 100 \times \left(1 - P_f/P_m\right)$$

Data from three conventional road-based triathlons were also accessed for three consecutive years: 2007, 2008, and 2009. These races were chosen because they are considered as the most competitive races for each distance. The first race was the Olympic distance world cup Hy-Vee triathlon, a race in which drafting on the bike is permitted and where males and females raced on the same day (Des Moines, IA, USA, http:// http://www.triathlon.org/results/). This race was chosen for the analysis because it is very competitive, especially since it regularly offers significant prize money. The Olympic distance world championships were excluded from the analysis because the men's and women's races took place on separate days in frequently different race conditions. The second race was the half Ironman (70.3) distance triathlon world championship (Clearwater, FL, USA, http://ironman.com/worldchampionship 70.3), a non-drafting authorized mixed race. The third race was the non-drafting mixed-sex Ironman distance triathlon world championship Kona, Hawaii, USA, http://ironman.com/worldchampionship).

Swimming, cycling, running, and overall performance times of the top 10 males and top 10 females at these races were analysed from 2007 to 2009. The mean overall performance times of the top 10 of the races was very similar between 2007, 2008, and 2009 for both males and females, so we pooled the 3 years of data. Therefore, for off-road, Olympic distance, half-Ironman, and Ironman triathlons, the performances of 30 male and 30 female triathletes (i.e. the top 10 of in 2007, 2008, and 2009) were used for comparisons of males and females between triathlon types and disciplines.

Statistical analysis

Data are reported as means ± standard deviations within the text and the table and displayed as means ± standard errors in the figures. Linear regressions were used to estimate changes in selected variables by year. Pearson's correlation coefficients were used to assess the association between various variables. Two-way analyses of variance (ANOVA: triathlon type × discipline) with repeated measures on disciplines was used to compare gender differences between the disciplines (swimming, cycling, and running) across the triathlon types. Tukey's *post hoc* analyses were used to test differences within the ANOVAs when appropriate (Statsoft, Version 6.1, Statistica, Tulsa, OK, USA). Statistical significance was set at $P < 0.05$.

Results

Trends in finish times of female and male winners at the Xterra® world championship are shown in Figure 1. The average time of the winners during the 1996–2009 period was 2:32:31 ± 06:03 and 3:02:26 ± 03:51 (h:min:s) for males and females, respectively. Since the race moved to a new location in 2005, the men's winning time remained stable and consistently above 2:35 (h:min). In contrast, there was a trend for the women's winning time to decrease since 2005. Differences in finish times between female and male winners as a percentage of the men's time declined significantly at a rate of 0.9% per year to around 13.8% in 2009.

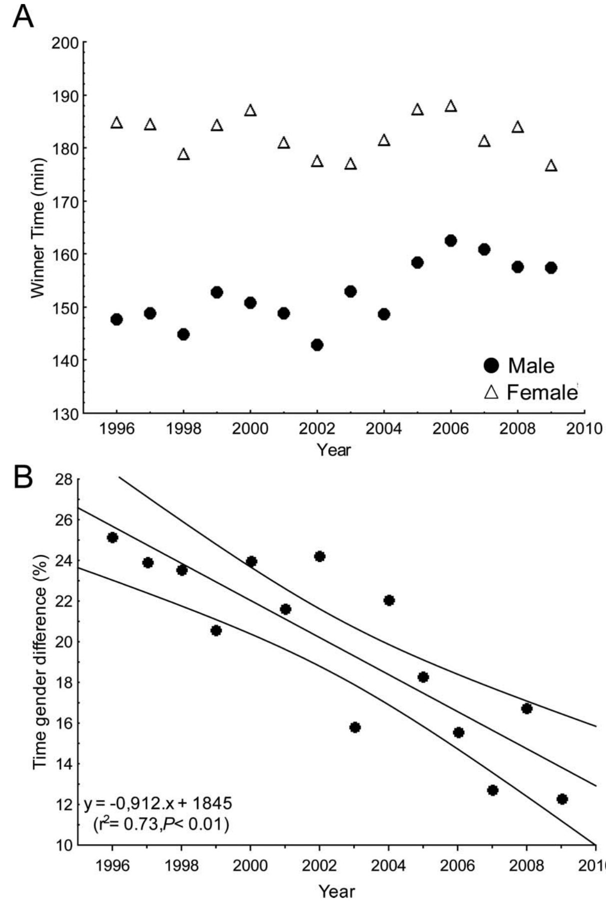

Figure 1. (A) Xterra® world championship finish times for the male and female winners from 1996 to 2009. In 1995, the Xterra® course moved to a new location. (B) Differences in finish times between the male and female winners expressed as a percentage of the men's winning time. The dotted curves represent the 95% confidence interval for the predicted value. The slope of the equation indicates the change in difference (%) between the sexes per year since 1996.

Figure 2 shows the historical performance trends of the top 10 males and top 10 females between 2005 and 2009 at the Xterra® world championship. During this period, the average performance times for swimming, cycling, running, and overall event were 0:20:58 ± 00:47, 1:35:34 ± 01:40, 0:46:31 ± 00:37, and 2:43:50 ± 02:19 (h:min:s) respectively for males, and 0:24:08 ± 01:16, 1:54:20 ± 01:52, 0:55:45 ± 01:37, and 3:15:19 ± 04:26 (h:min:s) respectively for females. Performance times in the three disciplines and total event were fairly stable for males, during 2005–2009. In contrast, for females, even though swimming and mountain biking performance times did not change, running and total time decreased significantly by ~1 min and ~2.5 min per year respectively. From 2005 to 2009, the average differences in time between the winners

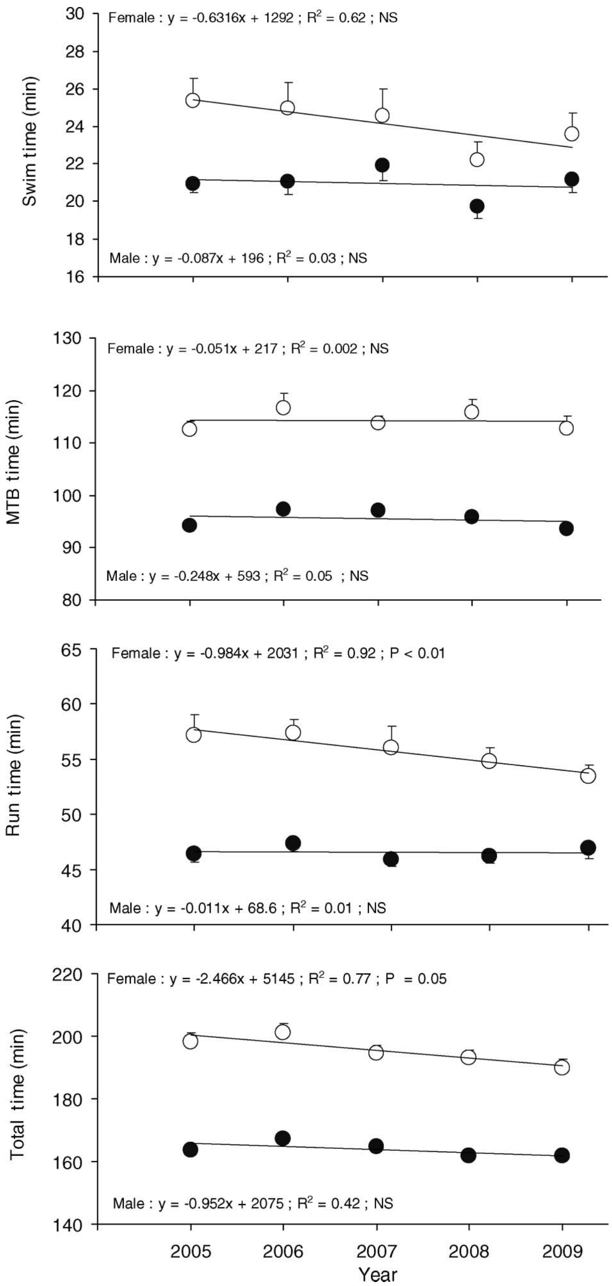

Figure 2. Mean swimming, mountain biking (MTB), running, and total performance times at the Xterra® world championship for the top 10 males (solid circles) and top 10 females (open circles) from 2005 to 2009. Values are means ± standard errors. The solid lines represent the linear regressions between 2005 and 2009. For females, the running time slopes decreased significantly by 1 min per annum and the total time decreased by 2.5 min per annum. For the males, the slopes were not different from zero. NS = non significant.

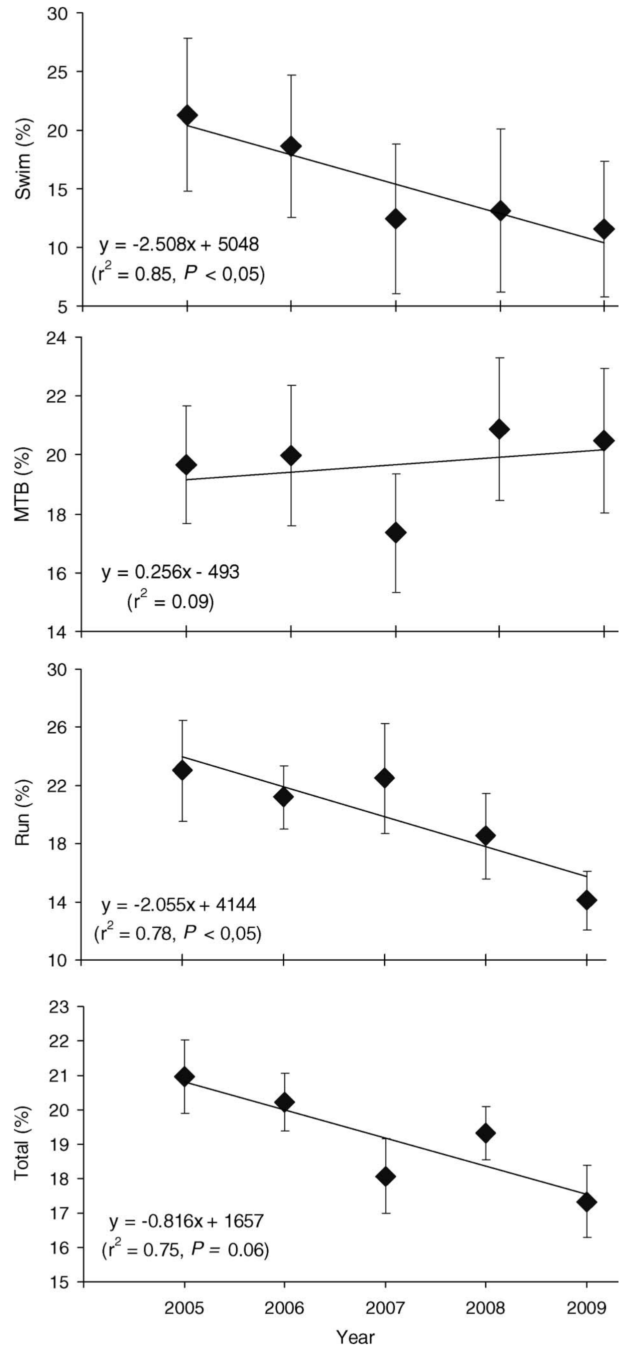

Figure 3. Mean percentage difference in time between the top 10 females and top 10 males for swimming, mountain biking (MTB), running, and total performance times at the Xterra® world championship from 2005 to 2009. Values are means ± standard errors. The slope of the equation indicates the change in difference (%) between the sexes per year since 2005.

and tenth-placed finishers remained stable and was equal to 5.1 ± 0.8% (8:12 ± 1:17 min:s) for males and 10.8 ± 1.4% (19:44 ± 2:25 min:s) for females.

Differences between males and females for swimming, cycling, running, and total event times between 2005 and 2009 are shown in Figure 3. Over this period, the average differences in performance times between the sexes for swimming, cycling, running, and overall event were 15.1 ± 4.4%, 19.6 ± 1.4%, 19.8% ± 3.7%, and 19.2% ± 1.5% respectively. Differences in swim and run times between the sexes over the 5 years decreased significantly by 2.6% and 2.1% per annum respectively, whereas differences for ride times remained fairly stable. This would suggest that the reduction in total time between males and females can be explained mostly by the reductions in swim and run times.

For the 2007–2009 period, differences in performance times between the sexes were significantly different between the disciplines for off-road triathlon (Figure 4A). Differences in performance times for swimming were significant lower than for mountain biking ($P < 0.01$) and trail running ($P < 0.05$). Differences in estimated power output between the sexes were also significantly different between the disciplines for off-road triathlon (Figure 4B). Finally, differences between the sexes in estimated power output were significantly greater for mountain biking than for swimming and running ($P < 0.01$).

Comparison with conventional triathlons

Table I shows the average performance times of the top 10 males and top 10 females for off-road and conventional triathlons with different distances for the 2007–2009 period. Compared with the Olympic distance conventional triathlon completed on a relatively flat course with drafting, off-road triathlon

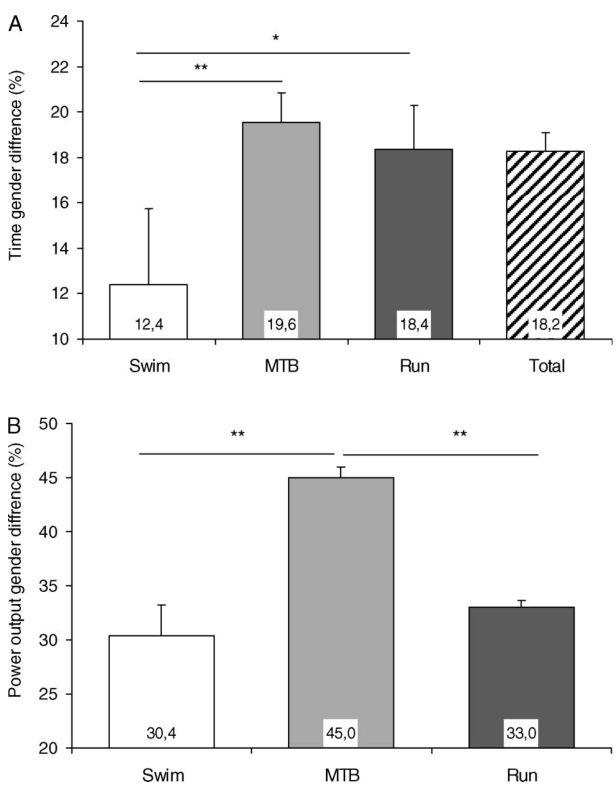

Figure 4. Mean percentage difference in performance time (A) and in estimated power output (B) between the top 10 females and top 10 males for swimming, mountain biking (MTB), running, and total performance times at the Xterra® world championship. 2007, 2008, and 2009: data pooled ($n = 30$ for each sex). Values are means ± standard errors. Significant difference: *$P < 0.05$, **$P < 0.01$.

Table I. Performances times (h:min:s) of the top 10 males and top 10 females for swimming, cycling, running, and all three legs combined for triathlons of different distances and relative contributions of each part of the overall performance.

	Swim		Cycle		Run		Total	
	Male	Female	Male	Female	Male	Female	Male	Female
Off Road 1.5/30/11 km	0:20:57 ± 01:48	0:23:37 ± 2:46	1:35:30 ± 2:47	1:54:08 ± 4:52	0:46:17 ± 1:41	0:54:45 ± 3:22	2:42:43 ± 2:39	3:12:27 ± 6:16
Time Contribution (% total time)	12.8 ± 0.4	12.3 ± 0.5	58.3 ± 0.7	58.6 ± 1.2	28.4 ± 0.5	28.5 ± 0.3		
Olympic Distance 1.5/40/10 km	0:19:14 ± 0:31	0:20:15 ± 0:37	0:59:45 ± 1:49	1:05:45 ± 1:49	0:32:13 ± 0:33	0:37:40 ± 1:26	1:52:02 ± 2:13	2:04:48 ± 2:19
Time Contribution (% total time)	16.8 ± 0.5	16.2 ± 0.4	51.7 ± 0.8	51.6 ± 1.0	29.5 ± 0.6	30.0 ± 0.8		
Half-Ironman 1.9/90/21 km	0:22:49 ± 0:58	0:25:59 ± 2:18	02:01:54 ± 2:18	02:16:02 ± 3:46	01:14:22 ± 2:35	01:25:21 ± 3:00	3:42:58 ± 4:09	4:11:34 ± 5:20
Time Contribution (% total time)	10.1 ± 0.4	10.2 ± 0.4	54.7 ± 0.6	53.7 ± 0.8	33.5 ± 0.4	34.4 ± 0.5		
Ironman 3.8/180/42 km	0:51:55 ± 1:35	0:57:52 ± 3:17	4:37 :03 ± 5:31	5:13:53 ± 7:41	2:53:06 ± 5:12	3:10:09 ± 9:03	8:26:19 ± 5:26	9:26:44 ± 11:18
Time Contribution (% total time)	10.1 ± 0.4	10.1 ± 0.5	54.4 ± 0.5	54.9 ± 0.7	34.7 ± 0.5	34.1 ± 0.4		

Note: Data pooled for 2007, 2008, and 2009). Off Road, Xterra® triathlon world championship (Makena, HI, USA); Olympic distance world cup triathlon, drafting race (Des Moines, IA, USA); Half Ironman, Half Ironman distance triathlon world championship, non-drafting race (Clearwater, FL, USA); Ironman, Ironman distance triathlon world championship, non-drafting race (Kona, HI, USA). Values are means ± standard deviations.

duration is about 50 min (i.e. 45%) longer for males and about 68 min longer (i.e. 54%) for females. Data in Table I show that the relative contributions of each part of the overall performance were similar for males and females but differed between the type and the distance of triathlons. When competition is longer, the contribution of swimming is smaller, since the distance of this segment does not increase proportionately (in time) with cycling and running. The swim contribution for Xterra® (~12%) is smaller compared with the swim contribution for Olympic distance triathlon (~16%), but greater compared with that of the half- and full-Ironman (~10%). Interestingly, the mountain biking contribution for Xterra® (~58%) is greater compared with the road cycle contribution of Olympic distance triathlon (~52%) and half- and full-Ironman (~54%). The run contribution for Xterra® (~28%) is similar to the run contribution for Olympic distance triathlons (~30%), but smaller than that of the half- and full-Ironman (~34%).

There was a significant interaction ($P < 0.01$) between triathlon type and discipline. Figure 5 shows the differences in performance times between the sexes for swimming, cycling, running, and overall event for triathlons with different distances (from Olympic to Ironman distance) for the top 10 elite males and top 10 elite females. Differences in performance times between the sexes for swimming were significantly ($P < 0.01$) lower for Olympic distance triathlon than for off-road triathlon. Compared with all conventional triathlons, differences between the sexes in off-road triathlon were significantly greater for cycling ($P < 0.01$). Differences in performance times between the sexes for running were also significantly ($P < 0.01$) greater for off-road than for Ironman triathlon.

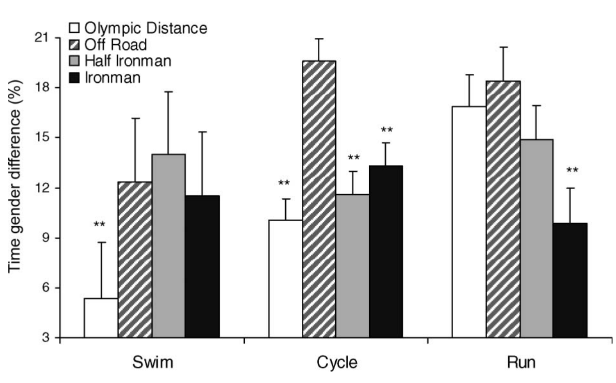

Figure 5. Mean percentage differences in performance time for swimming, cycling, and running at four triathlon events of different types (2007, 2008, and 2009: data pooled) between the top 10 females and top 10 males ($n = 30$ for each sex): Olympic distance, World Cup triathlon (Des Moines, IA, USA); Off Road, Xterra® triathlon world championship (Makena, HI, USA); Half Ironman, Half Ironman triathlon world championship (Clearwater, FL, USA); Ironman, Ironman triathlon world championship (Kona, HI, USA). Values are means ± standard errors. $^{**}P < 0.01$: significantly different from off-road triathlon.

Discussion

The major difference between off-road and conventional triathlon is seen in the cycling discipline, which is performed as mountain biking during off-road triathlon. Interestingly, the results showed that the contribution of mountain biking performance time to the overall time was greater at the Xterra® world championship (~60%) than for both conventional Olympic and long-distance triathlons. This highlights the importance of mountain biking in off-road triathlon performance and could explain why the profile of Xterra® triathletes are different from those of conventional triathletes. Indeed, some elite Xterra® triathletes originate from mountain bike racing, which gives them a distinct advantage in Xterra® triathlon (e.g. the 2008 Xterra® world champion also finished 21st at the cross-country mountain biking world championship the same year). The specialization of elite Xterra® triathletes in the field of triathlon might also explain the small number of triathletes placed in the top three since 1996. Indeed, just 19 female and 20 male triathletes filled the 42 podium places available between 1996 and 2009 (14 years).

The change of location of the Xterra® world championship since 2005 makes it difficult to conduct a global analysis of changes in performance since the first event in 1996. However, independent of course location, the results clearly show that the relative differences in finish times between the female and male winners diminished over the last 14 years to around 13% in 2009. The specific analysis of elite male and female performances over the 2005–2009 period provides a better insight into the contemporary performances in Xterra® triathlon. During this 5-year period, the performance times in the three disciplines and the event as a whole remained fairly stable for elite male triathletes. In contrast, elite female triathletes improved their running times by 6.8% over 5 years, and consequently their total event times, since swimming and mountain biking performance times were not significantly altered during this period. Similar observations have been made for Ironman triathlon where elite females have improved their running times over the last decade (Lepers, 2008). The reasons for such improvements in female running performances at Xterra®, however, are unclear. One explanation could be the change in profile of Xterra® elite female triathletes. In 2005, elite female competitors came predominantly from mountain biking, whereas over the following two years some elite female triathletes, usually racing

Olympic distance road-based events, started to compete in Xterra®. This new field of female competitors has helped to reduce the swimming and running time gaps, but not the mountain biking time gap, with their male counterparts (Figure 3).

Over the past three years (2006–2009), differences in performance times between the sexes for off-road triathlon were lower for swimming than for mountain biking and running. Lepers (2008) and Lepers and Maffiuletti (2010) reported similar findings for Ironman distance triathlon. The differences between swimming and the two other disciplines can be explained in part by the morphological differences in relative body fat, which is 7–9% higher in females than males (O'Toole, Hiller, Crosby, & Douglas, 1987). Greater body fat may represent a limitation during weight-bearing activities such as running and climbing in cycling, whereas it increases buoyancy in the water. Other factors such as underwater torque and mechanical efficiency of swimming corrected for body surface area have been found to be more efficient for females than for males (Pendergast, Di Prampero, Craig, Wilson, & Rennie, 1977), and could also explain the less marked differences between males and females in swimming compared with running and cycling.

The calculation of power during swimming and cycling is accurate only if the triathletes do not draft (i.e. swim or cycle behind another athlete). However, drafting during swimming was not controlled and therefore it might have influenced the assumed drag coefficient, thus invalidating the estimation of power output in swimming. The top international Olympic distance triathlons (i.e. World cups and World championships) have all been draft legal for several years. We failed to identify a reference high-level Olympic distance triathlon without drafting for comparison. This limitation allowed us only to compare differences in performance times between the different triathlons and not power output. Due to the steep gradients encountered on the mountain biking course, we assumed that the effects of drafting were minimal on the bike. Power output in swimming and cycling is related to an exponential expression of velocity while it is directly related to velocity during running. A difference of 20% between men and women in cycling performance time (or velocity) does not therefore correspond to a difference of 20% in physiological capacity, since power output in cycling depends on the third power of velocity. Because power output is proportional to oxygen uptake, the magnitude of differences in power output provides a more precise representation of underlying differences in physiological capacity between males and females (Seiler, Koning, & Foster, 2007). The greater maximal aerobic and anaerobic power relative to body weight in males than female triathletes (Bernard et al., 2009; Le Meur et al., 2009) may explain the differences between the sexes in estimated power output for the three disciplines. However, the difference in estimated power output between males and females was significantly greater for mountain biking than for swimming and running. Moreover, the model used here to compare the differences in power output between the sexes for cycling, based on the assumption of a level terrain, is not really adequate for the Xterra® mountain biking course, which includes significant ascent and descent sections. Indeed, the effect of gravity is not taken into account in the model, and the differences in power output between the sexes for mountain biking are probably underestimated. To accurately quantify the differences in power output between the sexes during mountain biking, special equipment such as power output ergometers attached to the mountain bikes will be necessary in future field studies.

Despite the similar swimming distances in off-road and short-distance triathlons (1.5 km), swimming times in off-road triathlon appear to be longer compared with short-distance triathlon for both males and females. This observation suggests that the performance at least in swimming might differ between elite off-road and short-distance triathletes. Differences in cycling were much greater between the sexes for off-road than for conventional road-based triathlon events. Mountain biking differs in many points from road cycling. Factors other than aerobic power and capacity such as off-road cycling economy, anaerobic power and capacity, and technical ability might influence off-road cycling performance (Impellizzeri & Marcora, 2007). It is assumed that triathletes, who switch from on-road to off-road triathlon without a great deal of specific training, might encounter some difficulties with the mountain biking leg of Xterra® triathlon.

It has been reported that during a cross-country mountain biking race of 2 h duration, more than 80% of the race is spent above the lactate threshold (Impellizzeri, Sassi, Rodriguez-Alonso, Mognoni, & Marcora, 2002). The mountain biking leg of the off-road triathlon lasts ~1 h 30 min for males and ~2 h for females, suggesting that time spent above the lactate threshold is also important in off-road triathletes during a race. This very high intensity is related in particular to the climbs, forcing off-road cyclists to expend most of their effort against gravity, greater rolling resistance associated with the difficult terrain conditions, and the isometric contractions of arm and leg muscles necessary for bike handling and stabilization. First, lower power-to-weight ratios for female compared with male triathletes (Bernard et al., 2009; Le Meur et al., 2009) inevitably leaves them at a disadvantage in the climbs. Second, lower arm and leg muscle strength in females compared with males may also place them at a disadvantage for bike stabilization during the descents. Finally, any differences in technical ability to control and stabilize the bicycle could also help to explain the greater differences between the sexes in cycling performance of Xterra® triathlon and conventional triathlon. However, this assumption needs to be confirmed with specific investigations of the effect of gender on technical ability in mountain biking.

Conclusion

To date, off-road triathlon has not attracted the interest of sport scientists. This paper is the first to describe the specific aspects of the off-road triathlon with regard to performance and gender. Elite male performance times at the Xterra® world championship stabilized over the 5 years studied, whereas of those of elite female triathletes continued to improve, especially on the run leg, probably due to the changes in profile of Xterra® elite female triathletes. Differences in power output between the sexes appear greater for mountain biking than swimming and running. The specific characteristics of mountain biking may also explain why differences in cycling between the sexes are greater for off-road than conventional on-road triathlon. Future studies will need to focus on the physiological basis of off-road triathlon and how it differs from conventional triathlon. We hope this paper will stimulate further research on the physiological profiles of Xterra® triathletes and physiological demands of Xterra® triathlons.

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