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The influence of swim, cycle and run performance on overall race outcome at the off-road triathlon world championships

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Abstract

The purpose of this study was to determine whether swim, cycle or run performance best predicts overall position during the off-road triathlon world championships. Data were collected for the top 10 finishers at each male and female world championships between 2007 and 2016. Linear regression was used to predict the influence of each discipline on finishing in the top 10 overall over the 10 years, whilst one-way between subjects analysis of variance (ANOVA's) were conducted to determine any differences in mean overall finishing time, swim, cycle and run times of the top 10 finishers between years. Cycling best predicted overall position (R^2 = 0.31), followed by the run and swim (R^2 = 0.17 and 0.16, respectively) for males. For females the run best predicted overall performance (R^2 = 0.46), then the cycle and swim (R^2 = 0.26 and 0.15, respectively). ANOVA analyses found significant differences for males in swim time ($F_{9,99}$ = 4.32; p < 0.001; η_p^2 = 0.30), cycle time ($F_{9,99}$ = 48.33; p < 0.001; η_p^2 = 0.83), run time ($F_{9,99}$ = 22.89; p < 0.001; η_p^2 = 0.70) and overall time ($F_{9,99}$ = 59.12; p < 0.001; η_p^2 = 0.86). Similarly, significant differences were also found for females in swim time ($F_{9,99}$ = 3.60; p = 0.001; η_p^2 = 0.26), cycle time ($F_{9,99}$ = 37.14; p < 0.001; η_p^2 = 0.79), run time ($F_{9,99}$ = 13.77; p < 0.001; η_p^2 = 0.58) and overall time ($F_{9,99}$ = 28.17; p < 0.001; η_p^2 = 0.74) by year. Results indicate there are differences in the influence of each discipline for males and females over the 10 years and by each year. Environmental conditions and competitive background may be influential in these findings.

Keywords: Triathlon; Performance; Off-road; Gender

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Introduction

The off-road triathlon world championships (Xterra®) takes place annually in October in Kapalua on the island of Maui (Hawaii, USA) and involves athletes competing over a 1.5 km sea swim, 32 km mountain bike (MTB) cycle and a 10.5 km trail run. At elite level both Xterra® and conventional road-based Olympic distance triathlons are draft legal, meaning athletes can swim, cycle and run in packs to conserve energy. McCole et al. (1990) reported that cycling behind other competitors could reduce energy cost by as much as 30 %. Additionally, Hue et al. (1998) and Hausswirth et al. (2001) both found that prior cycling behind other riders resulted in faster run times than when cycling alone in triathletes. However, given the off-road nature of Xterra®, such benefits from drafting may be limited.

The physiological demands of MTB has been well documented and described as requiring both aerobic and anaerobic efforts (Stapelfeldt et al. 2004; Impellizzeri et al. 2005; Gregory, Johns and Walls 2007). Unlike road-based triathlon courses, which predominantly consist of flat sections and smooth, tarmac climbs with relatively gradual inclines, MTB courses are characterised by numerous short, steep technical climbs, with governing body regulations stating courses must be comprised of a minimum of 40 % climbing per lap (Union Cycliste Internationale, 2012). Additionally, MTB courses include obstacles such as rocks and roots that riders must negotiate. Therefore, a high level of balance, agility and skill are also required (Hurst et al. 2012). Consequently, due to the technical terrain MTB riders encounter they are required to make frequent high intensity, surging efforts with overall exercise intensity being greater than that reported for road cycling (Lucia et al. 1999; Lee et al. 2002), as they rarely experience prolonged periods of lower intensity activity as is observed in road cycling. Additionally, MTB course profiles often dictate that riders must cycle in single file. Therefore, the benefits of drafting may be limited.

Similar technical demands may also be evident in off-road trail running. Though limited data still exists on the physiological and biomechanical differences between trail and road running, Creagh and Reilly (1997) found the oxygen cost of trail running during orienteering events to be between 26-72 % greater than comparable road running, dependent upon surface and gradient. Additionally, they also reported a decrease in stride length, increased knee lift and a rise in the centre of mass during off-road running when compared to road running.

Due to the draft legal nature of elite level road-based triathlons, previous research has investigated how much swim, bike and run position influence final finishing position in Olympic distance triathlons. Landers et al. (2008) found that in 90 % elite male races and 70 % elite female races at World Cup level, the eventual winners exited the swim in the first pack, though they also concluded that the ability to run well of the bike was the strongest predictor of performance. As position during the cycle leg did not change much, this was deemed the least important phase in determining overall position. However, in contrast to this, Dengel et al. (1989) had previously reported that swim time was least related to overall performance (r = 0.30), whilst running (r = 0.97) and cycling (r = 0.81) were the stronger predictors in non-draft legal events.

Despite the wealth of research into conventional triathlon, limited data exists on the demands of off-road triathlon. Lepers and Stapley (2010) investigated differences in gender and performance over 10 years (2005-2009) at the Xterra® World Championships. However, whilst they reported trends in mean finishing time and for each discipline over the 10 years, they did not determine which discipline best predicted overall performance and whether this differed between genders. Given the different demands, terrain and technical requirements of Xterra® racing, the importance of the swim, bike and run disciplines to overall performance may differ to that observed in elite level road triathlons. Therefore, the aims of this study were to 1) determine the influence of swim, bike and run performance on overall finishing position for males and females at the Xterra® World Championships between 2007 and 2016 and 2) provide an update to Lepers and Stapley (2010) on historical trends for the top 10 male and female finishers between 2007 and 2016. It was hypothesised that the cycle leg would be more influential to overall performance, than reported for road-based triathlons.

Methods

The study was approved by the University of Central Lancashire's STEMH ethics committee and conducted in accordance to the ethical standards outlined by Harriss and Atkinson (2011). Permission was granted by the Xterra® Corporation to use data from their World Championship events between 2007 and 2016. Data from both the male events (total number of riders = 402) and female events (total number of riders = 229) were downloaded from the Xterra® website http://www.xterraplanet.com/worlds/results/. The top 10 male and female athletes in each championship race were then used for data analyses.

The Xterra® World Championships course involves a 1.5 km sea swim, 32 km mountain bike route with 945 m of elevation change and an 10.5 km trail run with 346 m of elevation change, which traverse the West Maui Mountains. Course map and profiles are shown in Figure 1.

Statistical analysis

All data were analysed using the statistical software package SPSS (version 23, SPSS Inc., Chicago, IL). Data were first analyses using the Kolmogorov-Smirnov test to confirm normal distribution of data. The alpha level was set at $p \leq 0.05$. Linear regression analyses were used to determine whether the swim, cycle or run best predicted a top 10 overall finishing position for males and females over the 10 year period. One-way between subjects analysis of variance (ANOVA's) were conducted to determine any differences in mean overall finishing time, swim, cycle and run times of the top 10 finishers between years. Bonferroni *post-hoc* corrections were used to establish were significant differences occurred. Effect sizes were calculated using a partial Eta^2 ($\eta_p{}^2$) and classified as small (0.01), medium (0.09) and large (>0.25) (Cohen 1988). Finally, independent t-tests were run to establish any significant differences in mean times between genders for the 10 year period analysed. As with the Lepers and Stapley (2010) paper, the mean of the top 10 finishers were used for analyses rather than the winning times to provide a better profile of performance changes over the years.

Data were also gathered for race day temperature (Celsius) and wind speed (kph) for each year from www.timeanddate.com. Figure 2 presents the temperature and wind speed recorded at 12 noon on race day.

Results

Regression analysis revealed all three disciplines significantly predicted overall finishing position for both males and females ($p < 0.001$). For males, the cycle best predicted overall position (R^2 = 0.31), followed by the run and swim (R^2 = 0.17 and 0.16, respectively). However, for females the run best predicted overall performance (R^2 = 0.46), then the cycle and swim (R^2 = 0.26 and 0.15, respectively).

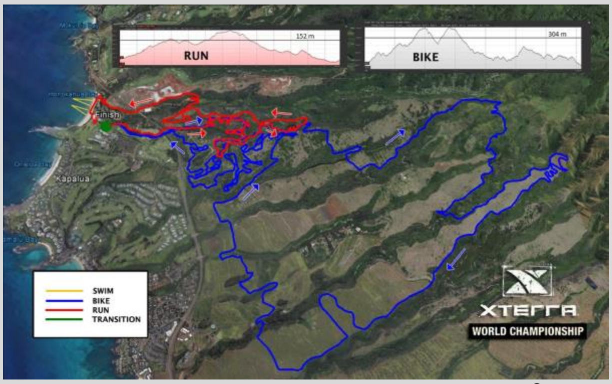

Figure 1. Course map and profile for the Xterra® World Championship race.

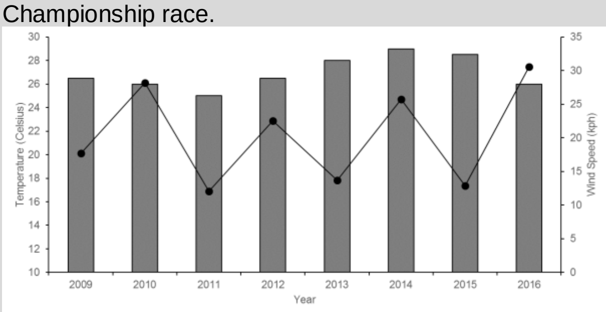

Figure 2. Temperature (bars) and wind speed (line) at 12 noon on race day by year.

Table 1. Summary of differences by year for male and female Xterra® performances.

Males	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Swim Time (min)	21.74 ± 1.85 ^{b}	19.60 ± 1.40 ^{a,e}	21.00 ± 1.56	20.26 ± 0.71 ^{e}	22.64 ± 1.30 ^{b,d,g}	21.17 ± 1.51	20.07 ± 1.25 ^{e}	20.84 ± 0.77	20.72 ± 1.00	21.20 ± 1.36
Cycle Time (min)	95.03 ± 2.27 ^{e,f,j}	93.72 ± 2.85 ^{e,f,j}	91.32 ± 2.21 ^{e,j}	91.31 ± 3.30 ^{e,j}	81.35 ± 2.13 ^{a,b,c,d,f,g,h,i,j}	86.90 ± 2.53 ^{a,b,e,f,g,h,i,j}	94.45 ± 2.84 ^{e,f,j}	92.02 ± 3.22 ^{e,f,j}	94.42 ± 4.17 ^{e,f,j}	109.01 ± 5.14 ^{a,b,c,d,e,f,g,h,i}
Run Time (min)	45.44 ± 1.33 ^{e,f,g,h}	46.03 ± 1.41 ^{e,f,g,h}	46.75 ± 2.09 ^{e,f,g,h}	44.85 ± 0.71 ^{f,g,h}	42.80 ± 0.94 ^{a,b,c,e,h}	39.52 ± 1.87 ^{a,b,c,d,e,i,j}	41.16 ± 2.20 ^{a,b,c,d,i,j}	40.31 ± 1.38 ^{a,b,c,d,e,i,j}	44.38 ± 2.44 ^{f,g,h}	44.31 ± 1.21 ^{c,f,g,h}
Overall Time (min)	164.41 ± 2.21 ^{d,e,f,g,h,j}	161.64 ± 2.41 ^{e,f,h,j}	161.48 ± 2.40 ^{e,f,h,j}	158.72 ± 3.58 ^{a,e,f,j}	149.10 ± 1.28 ^{a,b,c,d,e,g,h,i,j}	150.59 ± 2.29 ^{a,b,c,d,f,g,h,i,j}	159.00 ± 2.94 ^{a,e,f,j}	156.57 ± 3.68 ^{a,b,c,e,f,i,j}	162.50 ± 4.13 ^{e,f,i,j}	177.39 ± 5.36 ^{a,b,c,d,e,f,g,h,i}
Females										
Swim Time (min)	24.38 ± 3.21	22.03 ± 2.25 ^{e}	23.30 ± 2.53	22.29 ± 1.88 ^{e,b,d,g}	26.18 ± 2.27	24.28 ± 2.67	21.98 ± 2.03 ^{e,j}	23.11 ± 2.26	24.55 ± 2.55	25.72 ± 2.92 ^{g}
Cycle Time (min)	111.51 ± 3.33 ^{e,f,j}	113.55 ± 5.64 ^{e,f,j}	110.23 ± 5.41 ^{e,j}	110.47 ± 4.39 ^{e,j}	96.28 ± 3.08 ^{a,b,c,d,g,h,i,j}	103.37 ± 3.94 ^{a,b,g,j}	111.36 ± 1.48 ^{e,f,j}	106.34 ± 3.54 ^{e,j}	110.60 ± 4.28 ^{e,j}	133.84 ± 9.87 ^{a,b,c,d,e,f,g,h,i}
Run Time (min)	55.79 ± 4.66 ^{e,f,g,h}	54.59 ± 2.75 ^{f,g,h}	53.25 ± 2.23 ^{f,g,h}	51.87 ± 2.37 ^{f,g,h}	50.06 ± 3.79 ^{a,h}	45.60 ± 3.25 ^{a,b,c,d,i,j}	46.02 ± 1.83 ^{a,b,c,d,i,j}	45.17 ± 2.41 ^{a,b,c,d,e,i,j}	51.33 ± 4.47 ^{f,g,h}	52.11 ± 3.32 ^{f,g,h}
Overall Time (min)	194.15 ± 6.32 ^{e,f,g,j}	192.89 ± 5.65 ^{e,f,h,j}	189.57 ± 6.49 ^{e,f,h,j}	187.47 ± 5.14 ^{e,f,j}	175.27 ± 6.12 ^{a,b,c,d,i,j}	176.76 ± 6.87 ^{a,b,c,d,i,j}	182.95 ± 3.31 ^{a,j}	178.13 ± 5.77 ^{a,b,ci,j}	189.96 ± 9.03 ^{e,f,i,j}	215.25 ± 11.46 ^{a,b,c,d,e,f,g,h,i}

^{a} = significantly different to 2007; ^{b} = significantly different to 2008; ^{c} = significantly different to 2009; ^{d} = significantly different to 2010; ^{e} = significantly different to 2011; ^{f} = significantly different to 2012; ^{g} = significantly different to 2013; ^{h} = significantly different to 2014; ^{i} = significantly different to 2015; ^{j} = significantly different to 2016. Significant at the p < 0.05 level.

Table 2. Swim, cycle, run and overall times for the top ten males and females over the 10 years between 2007 and 2016.

	Males	Females	% difference (95% CI)
Swim time (min)	20.92 ± 0.86	23.78 ± 1.49*	11.89 (10.07-13.71)
Cycle time (min)	92.95 ± 7.03	110.76 ± 9.58*	16.00 (15.02-16.98)
Run time (min)	43.56 ± 2.49	50.58 ± 3.80*	13.76 (12.30-15.23)
Overall time (min)	160.14 ± 7.85	188.24 ± 11.65*	14.86 (13.92-15.80)

Data expressed as mean ± standard deviation. * indicates significantly different to males at an alpha level of p < 0.001.

When data were analysed by each year, ANOVA analyses found significant differences for males in swim time ($F_{9,99} = 4.32$; $p < 0.001$; $\eta_p^2 = 0.30$), cycle time ($F_{9,99} = 48.33$; $p < 0.001$; $\eta_p^2 = 0.83$), run time ($F_{9,99} = 22.89$; $p < 0.001$; $\eta_p^2 = 0.70$) and overall time ($F_{9,99} = 59.12$; $p < 0.001$; $\eta_p^2 = 0.86$). Similarly, significant differences were also found for females in swim time ($F_{9,99} = 3.60$; $p = 0.001$; $\eta_p^2 = 0.26$), cycle time ($F_{9,99} = 37.14$; $p < 0.001$; $\eta_p^2 = 0.79$), run time ($F_{9,99} = 13.77$; $p < 0.001$; $\eta_p^2 = 0.58$) and overall time ($F_{9,99} = 28.17$; $p < 0.001$; $\eta_p^2 = 0.74$) by year. Table 1 presents mean ± standard deviations for mean swim, cycle, run and overall times for the top 10 male and female finishers by year and where post-hoc differences occurred.

Mean times of the top ten by gender over the 10 year period were significantly different for each discipline between males and females (p <0.001). Table 2 summaries these means and the percentage difference between genders.

Mean winning time for males between 2007-2016 was 154.83 ± 6.91 min and for females 176.39 ± 9.41 min. This was again significantly different between genders (p < 0.001) and equated to difference of 12.18 % (95% CI = 11.14-13.21). Figure 2 presents the mean differences by year between genders when expressed as a percentage of the top ten mean male times for each discipline.

Discussion

This study aimed to determine which discipline best predicted overall performance at the Xterra® off-road triathlon World Championships between 2007 and 2016 and to provide an update to the Lepers and Stapley (2010) study on performance trends. It was hypothesised that the cycle leg would better predict overall performance than reported for road-based triathlons. However, the hypothesis was only partially accepted. Whilst all three disciplines significantly influenced overall performance for both males and females, the MTB cycle was the strongest predictor of a top 10 finish for males, yet the run was the best predictor for female athletes.

Contrary to Landers et al. (2008), the current study also supports the findings of Dengel et al. (1989), that the swim was the least important discipline when predicting final finishing position, for both males and females. This finding may further support the supposition that despite Xterra® being a draft legal event, the advantages of a good swim might not be carried over to the cycle and run. This is potentially due to the technical course profile and lack of opportunity to ride in a bunch to conserve energy following the swim. Whilst Dengel et al. (1989) reported values of $r = 0.97$ and 0.81 for cycle and run, respectively, the present study found values almost half this for the cycle and run for both genders. This suggests that whilst still significantly influential, the predictive power of the linear regression results were weaker than that for road-based triathlon. This again may be influenced by course terrain and environmental changes in weather over the selected 10 year period. Despite this, it remains unclear why the strongest predictor of overall performance differed between genders.

A possible explanation might be the influence of total bicycle and rider mass. Whilst anthropometric data for the athletes were not available, it is plausible that relative to body mass, the mountain bikes used were heavier for females than for males. This may have resulted in greater energy expenditure during the bike section for females. Subsequently, those females that were less fatigued and still able to run strongly after the bike would be more likely to finish with a high position overall. This could in part account for the run leg being more important for the female athletes. Further research is warranted to confirm this.

Another factor that might have influenced the findings of the current study, is the background of the athletes taking part in the Xterra® world championships. As previously allude to by Lepers and Stapley (2010), many of the elite male athletes come from a mountain biking background, as evidenced by the winners of the past three championships. Conversely, the females' event has seen a steady increase in the number of athletes who predominantly race road-based triathlons taking part, with the last three Xterra® world championships having been won by the current women's ITU World Triathlon Series champion. Subsequently, this may have helped improve running time but not MTB cycle times, as the run has been shown to better correlate to overall performance in road-based triathlon events (Landers et al. 2008).

With respect to changing trends, the mean winning time for males between 2007 and 2016 was comparable to that reported by Lepers and Stapley

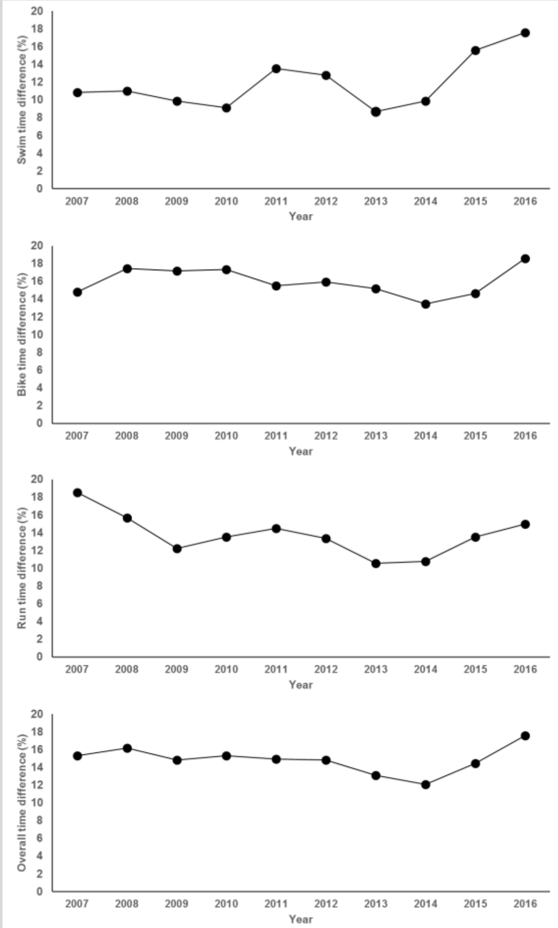

Figure 3. Gender differences in swim, bike, run and overall time expressed as a percentage of male finishing times.

(2010) for the 2005 to 2009 period, with only a 2 minute difference. However, between 2007 and 2016 the mean winning time for females decreased to 176.39 minutes compared to 182.26 minutes reported by Lepers and Stapley. This equated to approximately a 1 % decrease in the difference between male and female winning times compared to previously reported values (Lepers and Stapley 2010). This again, may be attributed to greater improvements in running times by females, particularly between 2007 and 2014. Mean times by discipline for the top ten finishers ranged between 11.89 and 16 % slower than those for the top ten male finishers over the 10 year period. Finding for the swim differences are consistent with previous studies (Tanaka and Seals 1997; Lepers and Maffiuletti 2010). Tanaka and Seals (1997) reported that the gender differences for swimming decreased as distance increased and found an almost identical 11% differences for 1500 m swim, the same distance as raced during Xterra®. The smaller gender differences during swimming were proposed to be due to better economy and efficiency of swimming in females than males.

With respect to cycling performance, differences were comparable to those reported by Rüst et al.

(2013) for duathlon racing (16 %). These differences may be down to differences in muscle mass. Knechtle et al. (2010) found that female triathletes had a 32 % lower muscle mass compared to male triathletes, which they proposed might be responsible for the 14 % lower maximum oxygen uptake reported. In addition, this lower muscle mass would also influence power-to-weight ratio, which may partly explain some of the differences between genders during the cycling leg, given the emphasis on climbing. However, for the run leg gender differences generally decreased between 2007 and 2014. This again may have been influenced by the greater influx of road based female triathletes entering the competition compared to males, as road based triathlon performance has been highly correlated to running performance (Landers et al. 2008).

Whilst there were significant differences between years for both male and female events, times for each discipline remained reasonably stable between 2007 and 2016, with the exception of 2011 and 2016. Times for these two years may provide support for the influence of environmental changes on performance, as historical weather data collected from www.timeanddate.com show 2011 had the lowest mean temperature (25 C°) and lowest wind speeds (12.07 kph) on race day across the 10 year period analysed. These condition may have positively affected the events, in particular the cycle section. However, this does not explain the increased swim time, though this could have been influenced by tides and swells in the sea. Similarly, 2016 showed the slowest times across all disciplines and overall for the 10 year period. It is likely the result of heavy rains and strong winds (30.58 kph) recorded prior to and during the event. Despite this specific year, there was a general pattern for improvement in performance by females. Whilst the mean age of the athletes is unknown, it is possible age may have played a factor in reducing the gender gap, as Rüst et al. (2013) found that female performance increased with increasing age. It would therefore be of interest to determine the mean age of male and female competitors at this event to determine whether age is indeed a factor in performance.

Conclusion

This study is the first to determine the links between split times, gender differences and overall performance in the Xterra® off-road triathlon world championships. The findings indicate that a strong mountain bike leg best predicts a top 10 finish for males, whilst running performance is most important to females. Overall finishing times for females were approximately 1 % slower than previously reported, though this may have been influenced by adverse weather conditions over the last three years.

Limitations and future directions

Whilst we acknowledge there are limitation with the current study, such as a lack of heart rate or power output data to better quantify the energetics, the data presented may still be of interest to the athlete and coach. However, future research should seek to collect physiological and biomechanical data, particularly power, oxygen consumption and running mechanics on Xterra® athletes to enable more accurate predictions to be made and comparisons to road-based triathletes and to further establish any gender differences specific to the Xterra® event.

Practical application

Based on the data presented here, female athletes could benefit greatly from specific mountain bike training to improve cycling performance and the ability to run faster off the bike. Conversely, male athletes may benefit from improving run performance off the bike, as a strong mountain bike performance may not always compensate adequately for a weak run.

Acknowledgement

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Conflict of interest

None.

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