

Participation and performance trends in ultra-triathlons from 1985 to 2009

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We examined the changes in participation and performance trends in ultra-triathlons, from the Double Iron (7.6 km swimming, 360 km cycling, 84.4 km running) to the Deca Iron (38 km swimming, 1800 km cycling, 422 km running), between 1985 (first year of a Double Iron) and 2009 (25 years). The mean finish rate for all distances and races was 75.8%. Women accounted for ~8–10% of the ultra-triathlons starters. For Double and Triple Iron, the number of finishers per year increased, from 17 to 98 and from 7 to 41, respectively. In the Deca Iron, the finishers per race have

remained <20 since the first event was held, up to 2009. Concerning World best performances, the men were ~19% faster than the women in both the Double and Triple Iron, and ~30% faster in a Deca Iron. With the increasing length of ultra-triathlons, the best women became relatively slower compared with the best men. Further investigations are required to understand why this gender difference in total performance time increased with the distance in ultra-triathlons.

The discipline of triathlon involves successively swimming, cycling and running. The traditional distances vary from the short (or Olympic) distance, i.e. 1.5 km swimming, 40 km cycling and 10 km running, to the Ironman distance, i.e. of 3.8 km swimming, 180 km cycling and 42.2 km running (Lepers, 2008). Triathlons of greater distances than the Ironman are usually called “ultra-triathlons,” such as the Double Ironman triathlon (2IMT) distance of 7.6 km swimming, 360 km cycling and 84.4 km running (Lehmann et al., 1995; Gastmann et al., 1998), the Triple Ironman triathlon (3IMT) distance of 11.4 km swimming, 540 km cycling and 126.6 km running (Knechtle et al., 2007a; Knechtle & Kohler, 2009), and the Deca Ironman triathlon (10IMT) distance of 38 km swimming, 1800 km cycling and 420 km running (Knechtle et al., 2007b).

The Ironman distance is the most popular long-distance triathlon. Since the first event was held in 1978, participation has increased, and nowadays thousands of triathletes compete in about 25 Ironman races all over the world in order to qualify for the Ironman Hawaii, where each year more than 1700 triathletes participate in the Ironman triathlon World Championship (Lepers, 2008; Lepers et al., 2010). The first ultra-triathlons, of distances greater than the Ironman distance, appeared since 1985.

Historically, the first 2IMT was held in 1985 in Huntsville (USA) where 23 athletes started. Then, in 1988, the first 3IMT was organized in Le Fontanil (France) with 11 starters. The first Quadruple Ironman triathlon (4IMT) was held in 1989 in Den Haag (the Netherlands) where two athletes started, and the first Quintuple Ironman triathlon (5IMT) was held in 1991, again in Den Haag (the Netherlands), with 10 starters. In 1992 the ultra-triathlon scene moved to Monterrey (Mexico) where 20 athletes started in the first 10IMT.

In the last two decades the ultra-endurance events, especially ultra-running and Ironman triathlon, have become more and more popular throughout the world (Lepers, 2008; Hoffman & Wegelin, 2009; Hoffman, 2010; Lepers et al., 2010). Participation and performance trends have previously been investigated for ultra-marathons (Hoffman & Wegelin, 2009; Hoffman, 2010) and triathlons (Lepers, 2008), but not for ultra-triathlons. Hoffmann and colleagues analyzed participation and performance trends in 100-mile ultra-marathons (Hoffman & Wegelin, 2009; Hoffman, 2010). In the “Western States 100-Mile Endurance Run,” they found an increase in starters from 1974 to 1986, and thereafter a stable entry. In 1986, the first women competed in that race. The participation among women has increased from

10–12% in the late 1980s to 20–22% where it has remained since 2001 (Hoffman & Wegelin, 2009). In the Hawaii Ironman triathlon, nowadays, 27% of the participants are women. The number of total starters at the Western States Endurance Run and at the Hawaii Ironman triathlon have been stable since 1990s because of a limitation in the number of entries than can be accepted rather than a lack of interest in participating in these events.

It has been suggested that gender differences in running would disappear over longer distances. Sparling et al. (1998) analyzed the World best times from the 1980s to 1996 for the 1500 m and marathon distances. In 1980, the marathon was a fairly new event for women. After an initial improvement, the best times for women have leveled off and remain ~ 11% behind the men. Coast et al. (2004) investigated the distances between 100 m and 200 km. Also over longer distances speeds were different, with men being ~ 12% faster than women. Indeed, longer distances were associated with greater differences. Regarding the ultra-marathon distances, the finishing times of women improved relative to men throughout the 1980s, but then stabilized over the past two decades with the fastest women running ~ 20% slower than the fastest men. Interestingly, the average times of the fastest runners have not changed over the past two decades for either gender (Hoffman, 2010).

The aim of this study was to investigate the participation and performance trends of both men and women over the ultra-triathlon distances, ranging from 2IMT to 10IMT, from the beginning in 1985 until 2009. In the analysis of Ironman performances at the Ironman Hawaii from 1981 to 2007, performance times decreased in the beginning, but reached a plateau within 10 years (Lepers, 2008). Gender differences for the split times in swimming, cycling and running, and the total race time, were ~ 10% (Lepers, 2008). We hypothesized that for longer distances up to the 10IMT, there would be an improvement in performance over the 25 years, and male athletes would remain faster compared with women athletes.

Material and methods

All the race results from 2IMT to 10IMT, showing total times and the split times for swimming, cycling and running, were collected from 1985 to 2009 by two of the authors. All the race results were provided by the organizers of the different races. The total number of starts and finishes were considered even if some people likely completed multiple events. Linear regressions were used for estimating the changes of selected variables (total, swimming, cycling and running performances for both men and women winner of each race) across years. One-way ANOVA was used to compare gender difference in swimming, cycling, running and total time across ultra-triathlons. Data

analysis was approved by the Ethical Committee of the Canton, St. Gallen, Switzerland.

Results

Participation

The total number of starts and finishes for both men and women in the different ultra-triathlons, since the first year each event was held, are given in Table 1. The 4IMT and 5IMT appear to have been considered as “experimental” on the way to the longest ultra-triathlon distance, i.e. the 10IMT, and so the number of race starts and finishes in these events have been very small compared with the other ultra-triathlon distances. Therefore, we focused only on the 2IMT, 3IMT and 10IMT in the following results.

The number of starts in the 2IMT has progressively increased from 1985 to 2009 (number of starts in 1985: 23 men, 0 women; number of starts in 2009: 109 men, 12 women). Women accounted for ~ 10% of the 2IMT starts since 2000. The number of starts in the 3IMT has also increased since 1988: men starts ranging from 11 (in 1998) to 69 (in 2000) and women starts ranging from 0 (in 1998) to 11 (in 1997). Women accounted for ~ 8% of the 3IMT starts since 1988. For 10IMT, the number of men starts ranged from 4 in 1998 to 24 in 2004 and the number of women starts ranged from 0 in 1995 to 3 in 2004. Women accounted for ~ 10% of 10IMT starts since 1992.

Figure 1 shows the changes in women and men finishers in the 2IMT, 3IMT and 10IMT distances since the first year of each race. For the 2IMT and 3IMT the total number of finishers has increased since the first year. In contrast, in the 10IMT, the total number of finishers decreased after the first year, until 1998, and then increased thereafter, until stabilizing from 2004.

Performance

Table 2 presents the actual World best times in the 2IMT, 3IMT and 10IMT, for both men and women, together with the corresponding swim, cycle and run split times. When the World best total performance times were compared, gender differences were similar for the 2IMT and 3IMT (~ 19%), while it was greatest for 10IMT (~ 30%).

Figure 2 shows the historical performance trends of the women and men winners in the 2IMT from 1985 to 2009. Regression lines are presented for the total time, together with the three disciplines, for both sexes. The gradients of the regression lines demonstrate that swimming, cycling, running and total performance has not significantly changed over the last 25 years for both men and women.

Table 1. Total number of races, year of first race, total number of starts and finishes, and mean finish rate (\pm SD) for 2IMT, 3IMT, 4IMT, 5IMT and 10IMT from the year of the first race to 2009, inclusive

	Number of races	Year of first race	Overall		Men		Women		
			Starts	Finish rate (%)	Total of starts	Total of finishes	Finish rate (%)	Total of starts	Total of finishes
2IMT (7.6–360–84 km)	85	1985	1686	79.5 \pm 6.7	1549	1227	137	106	84.7 \pm 18.9
3IMT (11.4–540–126 km)	48	1988	1101	72.2 \pm 10.5	1009	724	92	72	77.0 \pm 24.5
4IMT (15.2–720–168 km)	5	1989	64	68.7 \pm 18.5	62	41	2	2	100.0 \pm 0
5IMT (19–900–210 km)	4	1991	59	80.1 \pm 21.1	49	36	10	9	95.0 \pm 8.7
10IMT (38–1800–420 km)	10	1992	147	78.4 \pm 16.6	131	111	16	8	55.5 \pm 39.9

2IMT, Double Ironman triathlon; 3IMT, Triple Ironman triathlon; 4IMT, Quadruple Iron triathlon; 5IMT, Quintuple Iron triathlon; 10IMT, Deca Ironman triathlon.

The historical performance trends for both women and men winners in the 3IMT, from 1988 to 2009, are presented in Fig. 3. For men, the gradients of the regression lines demonstrate that cycling, running and total performances have not changed since 1988. In contrast, swimming performance times have tended to increase over this period. Surprisingly, for women, the total and running performance times have increased since 1988, while the swimming and cycling performances have remained stable over these last two decades.

Figure 4 shows the changes in performance times for both the women and men winners in the ten 10IMT held since 1992. The total swimming, cycling and running performances have not significantly changed since the first event for either men or women.

The average differences in the total, and in the swimming, cycling and running, times between the women and men winners at 2IMT, 3IMT and 10IMT are presented in Table 3. Gender differences for the total distances, together with the three disciplines, are in the same range for both the 2IMT and 3IMT, but are significantly greater for the 10IMT when compared with the 2IMT and 3IMT, except for running.

The trends in the top five men’s times’ spreads are shown in Fig. 5 for all the 2IMT, 3IMT and 10IMT held since 1985. The gradients of the regression lines demonstrate that the top five times’ spreads have not changed since the first event over any distance.

Discussion

The aim of this study was to investigate the participation and performance trends at ultra-triathlon events from 1985 to 2009. We hypothesized that an improvement in performance over the 25 years would occur, and that male athletes would be faster compared with female athletes. Apart from the study of Lepers (2008) at the Ironman Hawaii, and the studies from Hoffman and colleagues (Hoffman & Wegelin, 2009; Hoffman, 2010) in the 100-miles ultra-marathons in North America, this is the first study to describe the development of ultra-endurance events over 25 years, where the athletes pushed themselves to the limits of ultra-endurance performance. Interestingly, the length of the races for ultra-triathletes increased within a short period of time.

Participation and finisher rates

In 1985 the first 2IMT was held. Within 7 years the athletes had moved up to the 3IMT, the 4IMT and the 5IMT, and ultimately to the 10IMT. Owing to the low number of races over the 4IMT and 5IMT distances,

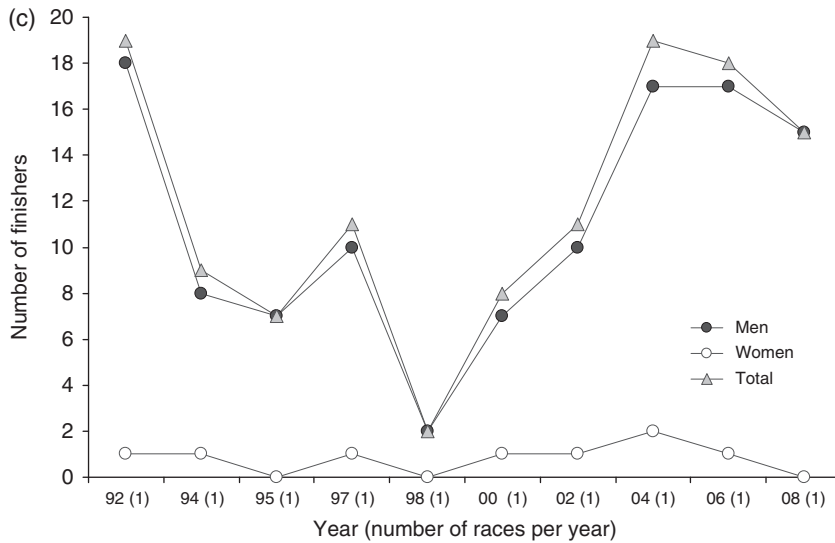
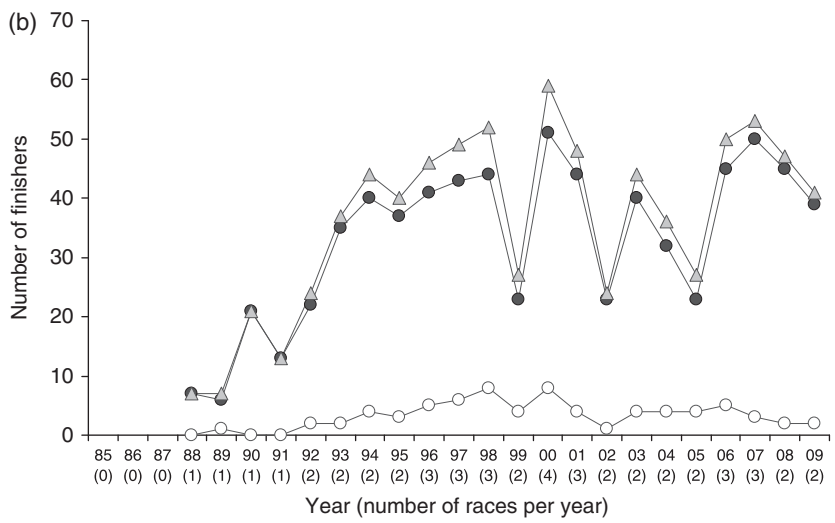
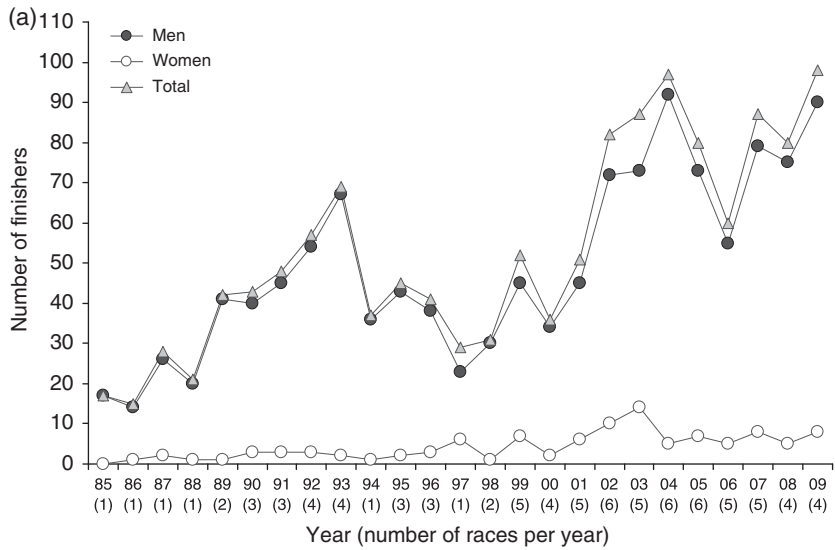


Fig. 1. Total number of finishers, and finishers of each sex, in the 2IMT from 1985 to 2009 (a), in the 3IMT from 1988 to 2009 (b) and in the 10IMT from 1992 to 2008 (c). The 10IMT was only held on even years. 2IMT, Double Ironman triathlon; 3IMT, Triple Ironman triathlon; 10IMT, Deca Ironman triathlon.

we focused our analysis on the 2IMT, 3IMT and 10IMT. While the organization of a 2IMT and 3IMT is not an insoluble logistic problem, distance

of more than the 3IMT require a closed circuit to traffic regarding the rules of the International Ultra-Triathlon Association. The only organizer who is able

Table 2. World best total event performance times for men and women with corresponding split times for swimming, cycling and running for 2IMT, 3IMT and 10IMT

	Country (year)	Total race time (min)	Swim time (min)	Cycle time (min)	Run time (min)
2IMT					
Men	Belgium (1993)	1194	124	628	441
Women	Belgium (1992)	1425	165	761	499
Difference (%)		19.3	33.1	21.2	13.2
3IMT					
Men	Germany (2003)	1907	229	987	690
Women	Germany (1996)	2274	236	1215	823
Difference (%)		19.2	3.1	23.1	19.3
10IMT					
Men	Mexico (1997)	11 528	671	6026	4829
Women	Mexico (1992)	14 954	1383	7194	6376
Difference (%)		29.7	106.1	19.4	32.0

Gender difference is expressed as a percentage of the men's time.

2IMT, Double Ironman triathlon; 3IMT, Triple Ironman triathlon; 10IMT, Deca Ironman triathlon.

to offer for weeks a closed circuit is the organizer in Monterrey, Mexico, where nearly all races of 5IMT and longer were held (Knechtle et al., 2007b).

With the increasing length of the races, the number of participants dramatically decreased. The rate of male finishers in all distances was ~ 80%, whereas it varied – due to the low number of participants – in females, between 55% for the 10IMT and 100% for the 4IMT.

In the “Western States 100-Mile Endurance Run” the participation of women increased between 1986 and 2007 to ~ 20% of all starters (Hoffman & Wegelin, 2009). The overall yearly finish rates have ranged from 48% to 80% since 1978, and the overall finish rate for men (64%) was comparable to that of women (62%). When all the 100-mile ultra-marathons in North America were analyzed, the average finisher rate was ~ 60% (Hoffman, 2010). For the ultra-triathletes, however, the mean finish rate was higher for both men (~ 78%) and women (~ 72%) over all the ultra-triathlon distances, compared with the 100-mile ultra-marathoners.

In the “Western States 100-Mile Endurance Run,” the average yearly number of starters was around 300 men and 50 women runners (Hoffman & Wegelin, 2009). With a total distance of 161 km and an average finish time between 25 and 30 h, the “Western States 100-Mile Endurance Run” is comparable to the shortest distance in ultra-triathlon, i.e. the 2IMT. Most of the ultra-triathletes participated in the 2IMT and in 3IMT. These two distances can be completed without sleep and at a rather high speed (Knechtle et al., 2007a, 2008a).

In ultra-triathlons, female participation was lower compared with the 100-mile ultra-marathoners (Hoffman & Wegelin, 2009). The number of women starters in the 2IMT has slightly increased and accounted for ~ 10% in the last 10 years; for the 3IMT and 10IMT, women starters were, from the

beginning of the events, at 8% and 10%, respectively. In the Ironman Hawaii, however, the number of women increased progressively from 20 in 1981 (6% of the participants) to more than 450 in 2007 (27% of the participants). Also in the “Western States 100-Mile Endurance Run” there was an increasing participation among women, to ~ 20% of all starters between 1986 and 2007 (Hoffman & Wegelin, 2009).

Performance trends

Regarding gender differences in performance, Lippi et al. (2008) analyzed the World records, including runs up to the marathon distance, from 1900 to 2007 where, overall, the relative improvement in athletic performance was higher in women than in men. Considering the World best performances in marathon running, men were ~ 11% faster than women from 1980 to 1996 (Sparling et al., 1998).

In ultra-endurance performances, there is still a debate about whether women could be faster than men. Bam et al. (1997) evaluated both men and women ultra-marathon performances and found that men ran faster over 5–42.2 km, but not in a 90 km ultra-marathon. It is, indeed, possible that a women ultra-runner can win a multi-stage ultra-marathon ahead of all the male competitors (Knechtle et al., 2008b). When performances over 100 m to 200 km between men and women were compared, men were, however, averaged 12.4% faster compared with women (Coast et al., 2004). Also in a 100-mile ultra-marathon, the fastest women were ~ 20% slower compared with the fastest men (Hoffman, 2010).

In the 2IMT and 3IMT, the World best performance times for men were 19.3% and 19.2% faster compared with women. For all winners, men were 25.6% faster in the 2IMT and 21.4% faster in the 3IMT compared with women. For the 10IMT,

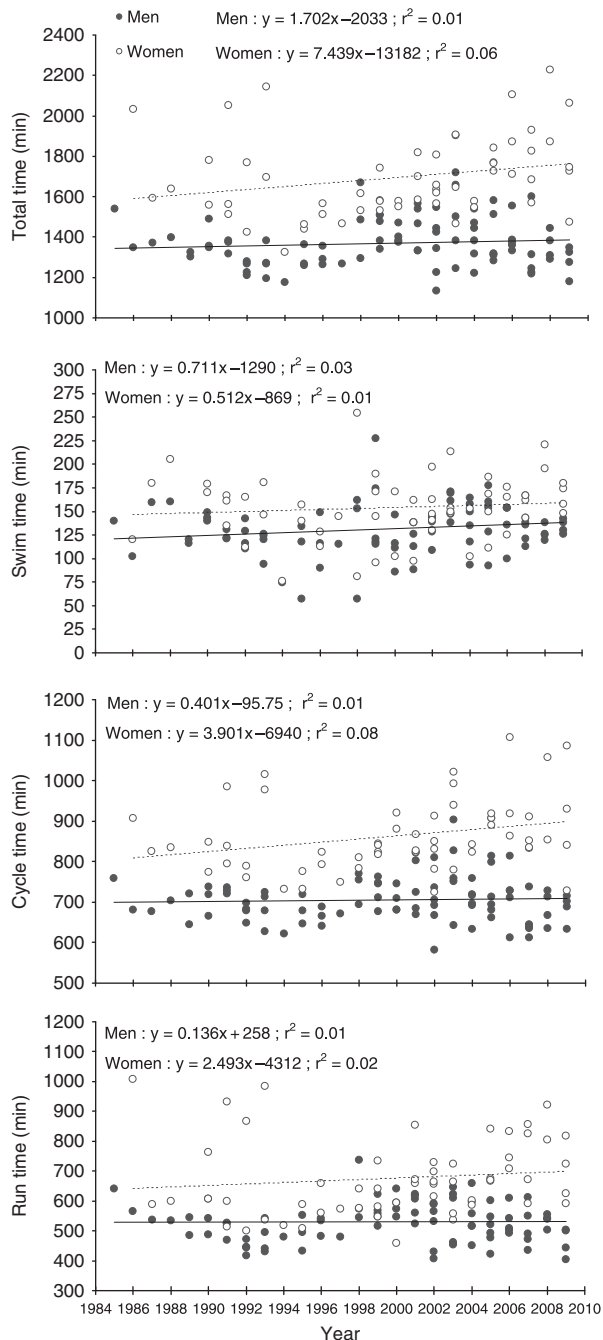


Fig. 2. Total, swimming, cycling and running performance times in the 2IMT, for both men and women winners, from 1985 to 2009. All winners were considered when several races took place the same year. Regression lines are presented as a bold line for men and a dotted line for women. 2IMT, Double Ironman triathlon.

World best performance was 29.7% faster for men. For all winners, men were 40.3% faster than women. The winner gender differences in performance times for both the 2IMT and 3IMT (~ 19%) are slightly greater comparable to those found for an Ironman (~ 13%) (Lepers, 2008). In all distances greater than the Ironman distance, women became progressively

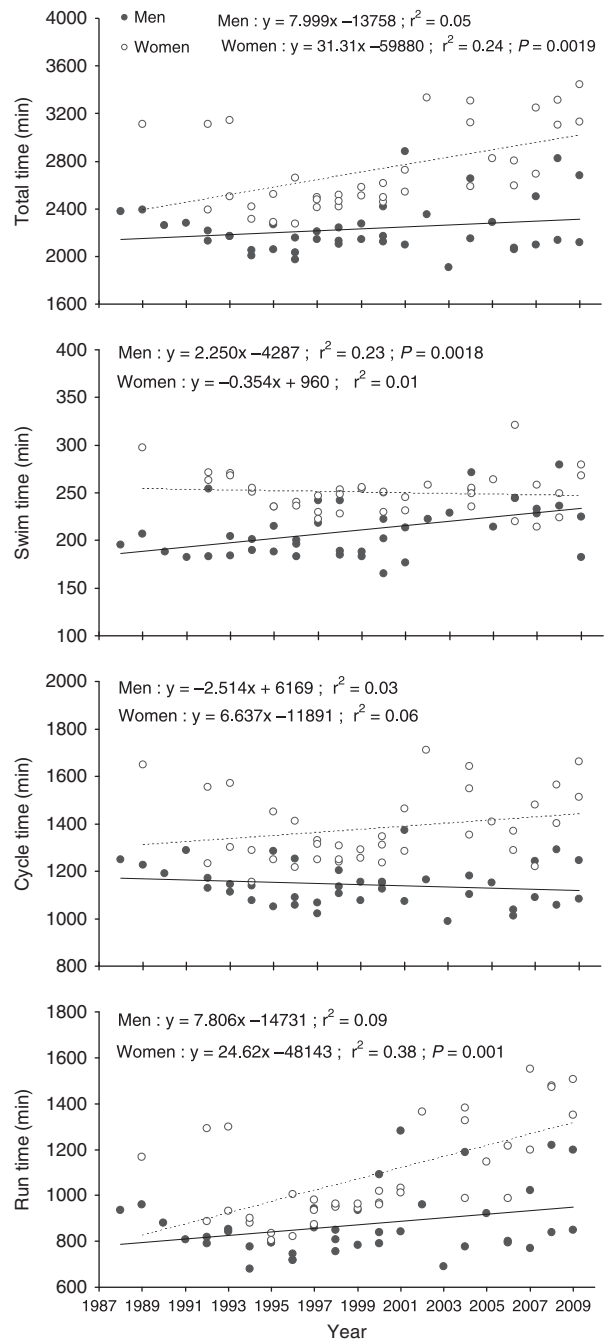


Fig. 3. Total, swimming, cycling and running performance times in the 3IMT, for both men and women winners, from 1988 to 2009. Regression lines are presented as a bold line for men and a dotted line for women. 3IMT, Triple Ironman triathlon.

slower than men. This finding is in accordance with the findings for runners when distances between 100 m and 200 km were investigated (Coast et al., 2004). It is possible that non-physiological factors may have contributed to these observations. For example, the widening of gender difference with increase distance could be due at least in part to the fewer number of women triathletes in 10IMT.

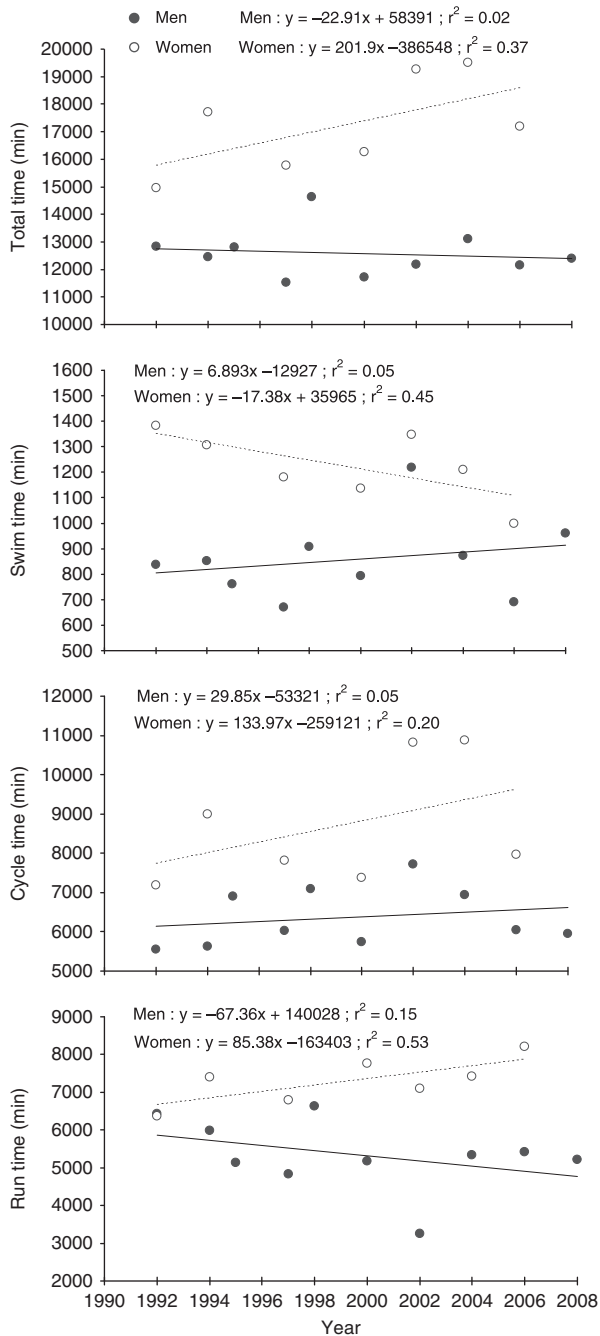


Fig. 4. Total, swimming, cycling and running performance times in the 10IMT, for both men and women winners, from 1992 to 2008. No race took place in 2009. Regression lines are presented as a bold line for men and a dotted line for women. 10IMT, Deca Ironman triathlon.

Performance in swimming, cycling and running

Considering total race time and the split times, male winners were ~ 20% faster for total race time, including split times, in the 2IMT and 3IMT. In the run split for the 2IMT, male winners were ~ 30% faster than female winners. In the 10IMT, male winners were ~ 40% faster than

females. In both the swim and run splits, male winners were ~ 45% faster than female winners. Regarding performance, neither split times nor the total race time became faster for men in the 2IMT, 3IMT and 10IMT during these 25 years. For the split times in the 3IMT, from 1988 to 2009, running performance increased for female winners and swimming performance increased for male winners. In the 2IMT and 10IMT, no changes for split times and total performances were found. For ultra-runners, Hoffman (2010) showed that the average times of the fastest runners had not changed over the last 20 years in the 161 km ultra-marathon in the United States. Also for the top five finishers among all men, or within different age groups, no changes could be detected (Hoffman & Wegelin, 2009).

The sport of triathlon involves three separate disciplines. In the Ironman Hawaii, between 1998 and 2007, the gender difference remained stable and practically identical for swimming (+0.1% per decade), increased a little for cycling (+0.8% per decade) and decreased somewhat more for running (-2.8%) (Lepers, 2008). In the 2IMT and 3IMT, the gender difference in time was the smallest in swimming and the greatest in running for both men and women winners. In the 10IMT, however, gender difference was the smallest in cycling.

In the Ironman Hawaii, time performances for the three disciplines, and for both sexes, decreased during the 1980s and tended to stabilize over the last two decades (Lepers, 2008). From 1988 to 2007, the change in swimming, cycling, running and total performance for both men and women was < 1.4% per decade, except for the women’s run time, which decreased by 3.8% per decade. So while running performance for women improved in the Ironman Hawaii, it declined in the 3IMT.

A further important finding was that with the exception of the World best time in the 3IMT for men, all the World best times were achieved in the early or mid 1990s. In 2000 no improvement in the World best times occurred for any distance. This finding is in line with global findings in the development of World records. When all the World records for Olympic disciplines were evaluated, a major global fading of World record progression was found (Berthelot et al., 2008).

How could these gender differences be explained?

It is well known that women are different regarding anthropometry, with women having more fat mass and less skeletal muscle mass compared with men (Sanborn & Jankowski, 1994). During ultra-endurance races such as the 3IMT, a loss of both muscle

Table 3. Differences in total swimming, cycling and running times between the female and male winners for all 2IMT, 3IMT and 10IMT races with at least one women finisher since the first event (mean ± CI 95%)

	Total (%)	Swim (%)	Cycle (%)	Run (%)
2IMT (n = 56)	25.2 ± 3.8	21.8 ± 7.8	23.3 ± 3.3	30.3 ± 6.6
3IMT (n = 36)	21.4 ± 4.9	19.3 ± 6.1	20.3 ± 4.2	24.6 ± 8.1
10IMT (n = 7)	40.3 ± 11.8 *,\$\$	47.4 ± 19.3 *,\$	39.5 ± 12.5 *,\$\$\$	45.9 ± 33.9

Gender differences are expressed as a percentage of men's time.

*P<0.05, **P<0.01: significantly different from 2IMT.

\$P<0.05, \$\$P<0.01: significantly different from 3IMT.

2IMT, Double Ironman triathlon; 3IMT, Triple Ironman triathlon; 10IMT, Deca Ironman triathlon.

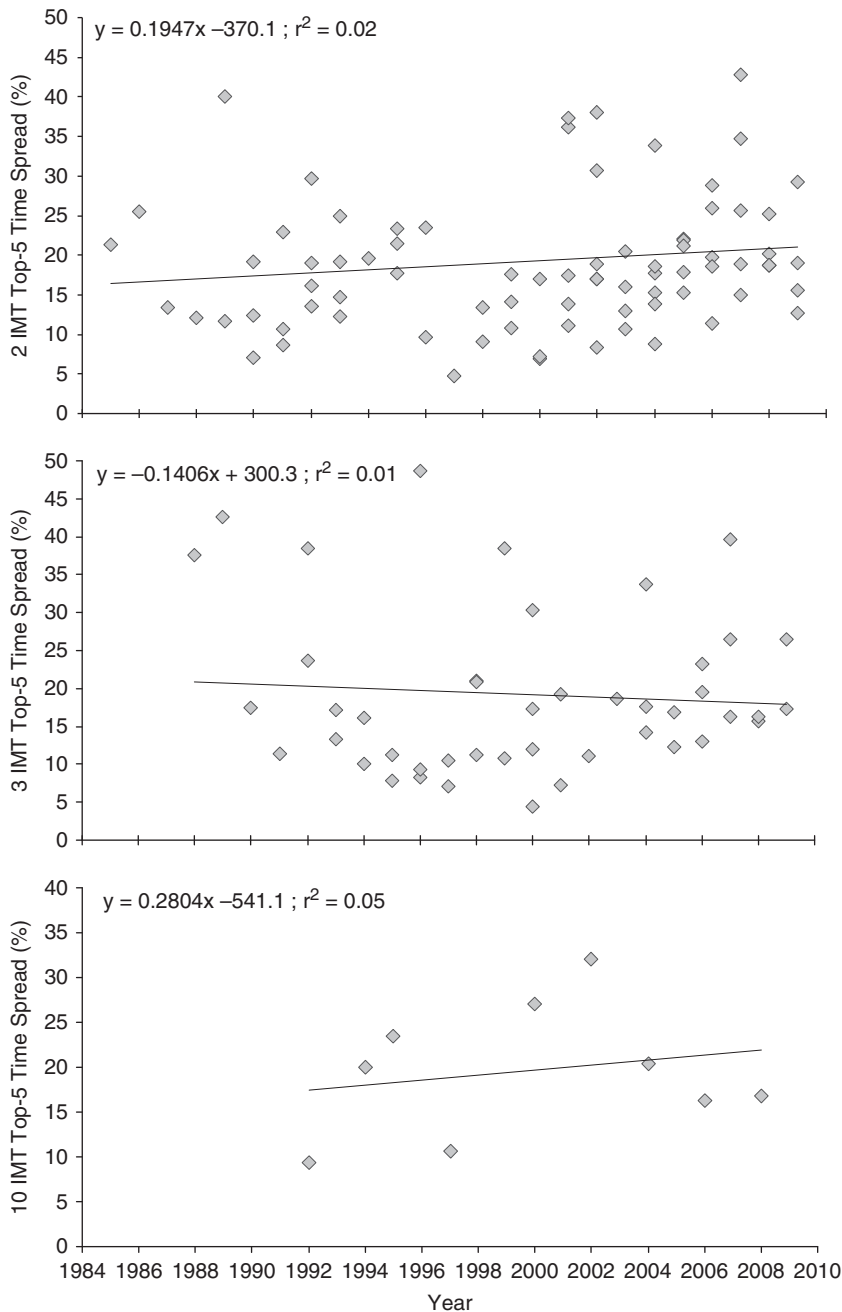


Fig. 5. Top five times' spreads for men across the times for the 2IMT, 3IMT and 10IMT with linear regressions shown by the solid lines. The gradients of the three distances were not different from zero. 2IMT, Double Ironman triathlon; 3IMT, Triple Ironman triathlon; 10IMT, Deca Ironman triathlon.

mass and fat mass has been described (Knechtle et al., 2008a). The decrease in skeletal muscle mass occurs in both women (Knechtle et al., 2008a) and men (Knechtle et al., 2008b) ultra-endurance athletes. When we consider that performance times increased for women with the increasing length in the ultra-distance races, we must assume that the smaller muscle mass at the start, and the decrease during the ultra-race, must be the limiting factor. Already in 1998, when the World best times from 1500 m to the marathon were compared, Sparling et al. (1998) concluded that the differences in performance will remain due to the biological differences between men and women.

Perspectives

Within 7 years, from 1985 to 1992, ultra-triathletes had moved progressively from the 2IMT to the 10IMT. While the 2IMT and 3IMT are of increasing popularity, the 4IMT and 5IMT seemed to be experimental toward a move to the 10IMT. Since performance in the 2IMT, 3IMT and 10IMT showed no improvement over 25 years, we assume that only ultra-endurance athletes of a very high level started ultra-triathlons from the initiation of the sport. Presumably, ultra-triathletes enter the scene in dis-

tances such as the 2IMT and 3IMT and then move later to the 10IMT. However, it is not known whether the best ultra-triathletes competing in the 2IMT and 3IMT will also be the best in the 10IMT. The relationship between the 2IMT and 3IMT performances to the 10IMT performances for the same athletes need to be further investigated. The mean finish rate for all distances was 75%, which is high compared with a 161 km ultra-marathon. With the increasing length of the races, women became relatively slower compared with men. So women seem not to be able to compete faster than men in ultra-endurance performances. With the increasing length of the races, the smaller skeletal muscle mass in women may be a limiting factor. Further investigations are required in order to understand why gender differences in total performance times increase with the distance in ultra-triathlons.

Key words: gender, sex difference, swimming, cycling, running, endurance.

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References

- Bam J, Noakes TD, Juritz J, Dennis SC. Could women outrun men in ultramarathon races? *Med Sci Sports Exerc* 1997; 29: 244–247.
- Berthelot G, Thibault V, Tafflet M, Escolano S, El Helou N, Jouven X, Hermine O, Toussaint JF. The citius end: world records progression announces the completion of a brief ultra-physiological quest. *PLoS One* 2008; 3: e1552.
- Coast JR, Blevins JS, Wilson BA. Do gender differences in running performance disappear with distance? *Can J Appl Physiol* 2004; 29: 139–145.
- Gastmann U, Dimeo F, Huonker M, Böcker J, Steinacker JM, Petersen KG, Wieland H, Keul J, Lehmann M. Ultra-triathlon-related blood-chemical and endocrinological responses in nine athletes. *J Sports Med Phys Fitness* 1998; 38: 18–23.
- Hoffman MD. Performance trends in 161-km ultramarathons. *Int J Sports Med* 2010; 31: 31–37.
- Hoffman MD, Wegelin JA. The Western States 100-Mile Endurance Run: participation and performance trends. *Med Sci Sports Exerc* 2009; 41: 2191–2198.
- Knechtle B, Duff B, Amtmann G, Kohler G. Cycling and running performance, not anthropometric factors, are associated with race performance in a Triple Iron Triathlon. *Res Sports Med* 2007a; 15: 257–269.
- Knechtle B, Duff B, Amtmann G, Kohler G. An ultratriathlon leads to a decrease of body fat and skeletal muscle mass – the triple iron triathlon Austria 2006. *Res Sports Med* 2008a; 16: 97–110.
- Knechtle B, Duff B, Schulze I, Kohler G. The effects of running 1,200 km within 17 days on body composition in a female ultrarunner – Deutschlandlauf 2007. *Res Sports Med* 2008b; 16: 167–188.
- Knechtle B, Knechtle P, Andonie JL, Kohler G. Influence of anthropometry on race performance in extreme endurance triathletes: world challenge Deca Iron Triathlon 2006. *Br J Sports Med* 2007b; 41: 644–648.
- Knechtle B, Kohler G. Running performance not anthropometric factors is associated with race success in a triple iron triathlon. *Br J Sports Med* 2009; 43: 437–441.
- Lehmann M, Huonker M, Dimeo F, Heinz N, Gastmann U, Treis N, Steinacker JM, Keul J, Kajewski R, Häussinger D. Serum amino acid concentrations in nine athletes before and after the 1993 Colmar ultra triathlon. *Int J Sports Med* 1995; 16: 155–159.
- Lepers R. Analysis of Hawaii Ironman performance in elite triathletes from 1981 to 2007. *Med Sci Sports Exerc* 2008; 40: 1828–1834.
- Lepers R, Sultana F, Thierry B, Hauswirth C, Brisswalter J. Age-related changes in triathlon performance. *Int J Sports Med* 2010; 31: 251–256.
- Lippi G, Banfi G, Favalaro EJ, Rittweger J, Maffulli N. Updates on improvement of human athletic performance: focus on world records in athletics. *Br Med Bull* 2008; 87: 7–15.
- Sanborn CF, Jankowski CM. Physiologic considerations for women in sport. *Clin Sports Med* 1994; 13: 315–327.
- Sparling PB, O'Donnell EM, Snow TK. The gender difference in distance running performance has plateaued: an analysis of world rankings from 1980 to 1996. *Med Sci Sports Exerc* 1998; 30: 1725–1729.