

An analysis of participation and performance by nationality at 'Ironman Switzerland' from 1995 to 2011

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Abstract

Triathlon, in particular the 'Ironman' distance, has become very popular in the field of ultra-endurance sports. The aim of the present study was to analyse the participation and performances at the 'Ironman Switzerland' in Zurich, Switzerland, regarding the nationality of the participants. Nationalities and performances of 21,399 athletes, originating from exactly 100 countries and competing between 1995 and 2011, were analysed. The mean total race times and changes across the years of the top ten athletes overall and of each country for both women and men triathletes were analysed using linear regression analyses. In total, 90% of the participants in 'Ironman Switzerland' originated from European countries, with triathletes from Switzerland (31.9%) and Germany (18.9%) presenting the majority, followed by participants from Great Britain (11.2%), France (7.9%), Italy (5.3%), USA (4.7%), Spain (3.5%), Belgium (2.7%) and Austria (2.6%). Switzerland presented the fastest triathletes in both sexes followed by athletes from Germany. Behind these two leading nations, triathletes from countries such as France, Belgium, Austria, Great Britain, Spain, Italy and USA competed slower. To summarize, 'Ironman Switzerland' has been dominated by central European triathletes regarding participation and performance. Most of the participants and the fastest finishers came from Switzerland, followed by triathletes from Germany. To assess these results, future studies need to investigate the leading nations in 'Ironman' qualifying races all over the world for 'Ironman Hawaii' and in the 'Ironman World Championship' in Hawaii.

Keywords: country, nationality, ultra-endurance, triathlon, performance

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Introduction

The 'Ironman' is a triathlon consisting of a 3.86 km swim, a 180.2 km cycling race and a 42.2 km marathon run and was first held in 1978 in Hawaii as a result of an argument about who would be the toughest endurance athlete of the world (Lepers 2008). Even with the upcoming of more challenging endurance events such as Double, Triple or Deca Ironman races and Ultramarathon races such as the 'Spartathlon' (www.spartathlon.gr), the 'Badwater Ultramarathon' (www.badwater.com) or the 'Marathon des Sables' (www.darbaroud.com), the 'Ironman' is a growing global event (Knechtle et al. 2011b, Knechtle et al. 2011c, Lepers 2008). The annual 'Ironman World Championship' of Ironman triathlon (<http://ironman.com/worldchampionship>) is held in

Kona, Hawaii (USA), where the best triathletes from all over the world compete (Lepers 2008).

There are limited slots available for the race, which can be obtained in one of the current 32 official qualifying races worldwide with 'Ironman' distances or 'Half-Ironman' distances (<http://ironman.com/events>). Europe offers the highest number of qualifiers in the world, presumably due to the high popularity of triathlon in Europe (Rüst et al. 2012a). Currently, nine qualifying events in Europe are held in Pembrokeshire (Wales), Bolton (England), Lanzarote (Spain), Nice (France), Frankfurt and Regensburg (Germany), Klagenfurt (Austria), Zurich (Switzerland) and since 2012 in Kalmar (Sweden) (<http://ironman.com/events>). With growing interest in ultra-endurance races worldwide, where an ultra-endurance race is defined as an endurance performance exceeding six hours (Zaryski and Smith 2005), there is an increasing economical and medical interest in these events (Burns et al. 2003; Egermann et al. 2003; Strock et al. 2006). Extensive research has already been conducted on different factors that may influence performance in ultra-endurance races such as anthropometric characteristics (Knechtle et al. 2007; 2011a; 2011b), training volume (Knechtle et al. 2010b; 2011b) or previous experience (Knechtle et al. 2010a). Furthermore, research has also focused on the effects of



age (Haupt et al. 2012; Knechtle et al. 2012; Lepers et al. 2012) and gender (Eichenberger et al. 2012; Knechtle et al. 2010a; 2010b; 2011c; Lepers and Maffioletti 2011; Rüst et al. 2012b) on ultra-endurance performance.

It has been previously shown that origin, nationality or affiliation to a certain ethnic group could influence performance of endurance athletes (Calo and Vona 2008; Eynon et al. 2011; Scott and Pitsiladis 2007). An example of the presence of a genetic predisposition that determines a superior performance is currently assumed and partly shown in East-African endurance athletes, who have been dominating long-distance running for more than five decades (Larsen 2003; Onywera et al. 2006; Onywera 2009; Scott et al. 2003; 2009). Consequently, it would be interesting to examine whether epidemiological factors also interact with performance in other endurance sports disciplines such as triathlon.

To initially find support for such a presumption it is necessary to find the nation with the fastest triathletes in the world and evaluate their performance. Regarding ultra-endurance, Rüst et al. (2012a) recently first analysed the aspect of nationality when considering the performance in Double Iron ultra-triathlons and showed a significant difference between European and North-American triathletes over the years with European triathletes dominating these races. As this is the first result regarding epidemiology in an ultra-endurance race, it has yet to be further supported.

The present study pursues the idea of possible epidemiological factors that predetermine a high level of performance for certain types of sports and is the first to show aspects of the epidemiology in the 'Ironman' triathlon. The aim was to investigate the participation and performance trends of triathletes competing in 'Ironman Switzerland' from 1995 to 2011 regarding their nationality. Since 1995, 'Ironman Switzerland' has been held in Zurich every year in July. By presenting more than 1,500 finishers in each race over the last five years, it is considered as an important 'Ironman' qualifier in Europe. We hypothesized that mostly European triathletes would attend the race, in particular from Switzerland and its neighbouring countries such as France (FRA), Italy (ITA), Germany (GER) and Austria (AUT), and dominate the 'Ironman Switzerland' regarding performance. Furthermore, we expected a high number of participants from European countries lacking an own qualifying race, in particular from Italy (ITA), the Netherlands (NED), Belgium (BEL), Ireland (IRL), Denmark (DEN), Greece (GRE) and the East European countries such as the Czech Republic (CZE), Poland (POL), Slovenia (SLO), Hungary (HUN), Croatia (CRO) and Slovakia (SVK).

Materials and methods

The present study was approved by the Institutional Review Board of St. Gallen, Switzerland, with a waiver of the requirement for informed consent given that the study involved the analysis of publicly available data. Data of 21,399 athletes from 100 different countries,

who have ever participated in the 'Ironman Switzerland' since 1995, were obtained from the race website (www.ironman.ch) as well as the race director and analysed regarding their nationality and performance, *i.e.* rank and overall race time. The study meets the ethical standards of the journal (Harriss and Atkinson 2011).

Data analysis

The changes in the numbers of women and men finishers, non-finishers and disqualified athletes were considered. To assess the origin of the athletes, countries that provided a total of at least 100 participants (*i.e.* finishers + non-finishers + disqualified athletes) were included. These countries covered a total of 20,300 triathletes and thus 94.9% of all participants. To analyse the development of the amount of participants and their performance by country, we examined the number of participants each year as well as the mean total race time of the top ten triathletes overall and subdivided by country. For the analysis by country, we included nations that provided at least 500 participants during 14 years since 1995. These nations were Switzerland (SUI), Germany (GER), Great Britain (GBR), France (FRA), Italy (ITA), United States (USA), Spain (ESP), Belgium (BEL) and Austria (AUT). However, in women, only Germany (GER) and Switzerland (SUI) provided a sufficient amount of triathletes, in men France (FRA), Great Britain (GBR), Germany (GER), Italy (ITA), Switzerland (SUI) and the United States of America (USA). To show significant differences in performances of the different countries, we ranked the top ten's mean total race times of both sexes by country and compared each adjoining nation.

Statistical analyses

In order to increase the reliability of data analysis, each set of data was tested for normal distribution as well as for homogeneity of variances previous to statistical analysis. Normal distribution was tested using a D'Agostino & Pearson's omnibus normality test and homogeneity of variances was tested using a Levene's test in case of two groups and with Bartlett's test in case of more than two groups. To find significant changes in the development of a variable across years, linear regression was used. To find differences between two groups a student's *t*-test was used in case of normal distribution and a Mann-Whitney test was used if data were not normally distributed. Performance times of the top ten athletes overall of each country were compared using one-way ANOVA with subsequent Tukey-Kramer post-hoc analysis. Statistical analyses were performed with IBM SPSS Statistics (Version 19, IBM SPSS, Chicago, IL, USA) and GraphPad Prism (Version 5, GraphPad Software, La Jolla, CA, USA). Significance was accepted at $P < 0.05$ (two-sided for *t*-tests). Data in the text are given as mean \pm standard deviation (SD).

Results

Participation trends

Figure 1 shows the development of the total number of finishers. The development was analysed using linear regression. Between 1995 and 2011, a total of 21,399 athletes participated in 'Ironman Switzerland'; 19,417 (90.7%) finished the race, including 2,079 women (10.7%) and 17,338 men (89.3%). In addition, 1,924 triathletes (9.0%) did not finish the race (*i.e.* non-finishers) and 58 athletes (0.3%) have been disqualified. Regression analyses showed a significant increase in the number of participants, from 198 athletes in 1995 to a maximum of 2,329 in 2010, where 1,764 athletes took part in 2011. Likewise, the increase in the number of finishers was significant for both women ($r^2 = 0.87$; $P < 0.001$) and men ($r^2 = 0.90$; $P < 0.001$).

Origin of athletes

Figure 2 shows the distribution of the triathletes' origins per continent. Participants from Europe provided the majority of 19,256 athletes (90%). The European triathletes attended from 39 different countries, with the majority from Switzerland (SUI) (6,817 participants; 31.9%) and Germany (GER) (4,049; 18.9%), followed by athletes from Great Britain (GBR) (2,386; 11.2%), France (FRA) (1,688; 7.9%), Italy (ITA) (1,131; 5.3%), Spain (ESP) (745; 3.5%), Belgium (BEL) (583; 2.7%), Austria (AUT) (551; 2.6%) and Ireland (IRL) (227; 1.1%). A total of 14,250 triathletes (66.6%) participated from Switzerland (SUI) or neighbouring countries such as Germany (GER), Italy (ITA), France (FRA), Austria (AUT) and Fürstentum Liechtenstein (LIE). From European countries without a qualifying race, which were amongst others Italy (ITA), Belgium (BEL), Ireland (IRL), Sweden (SWE), Denmark (DEN) and the Netherlands (NED), a total of 3,020 (14.1%) athletes participated. Triathletes from East-European countries such as the Czech Republic (CZE), Poland (POL),

Table 1. Current qualifying 'Ironman' distance races for the 'Ironman World Championships' in Hawaii with the corresponding year of the first race, the number of qualifying slots and the number of finishers in 2011. In the table were not included: five 'Half-Ironman' distance races offering 28-30 additional qualifying slots.

Year of first race	Location / Country	Qualification Slots	Number of Finishers
1985	Taupo, New Zealand	40	1.258
1985	Port Macquarie, Australia	40	1.017
1987	Penticton, Canada	50	2.599
1992	Lanzarote, Spain	50	1.207
1997	Zurich, Switzerland	50	1.593
1998	Klagenfurt, Austria	50	2.349
1999	Lake Placid, United States	50	2.352
1999	Florida, United States	65	2.439
2000	Florianopolis, Brazil	50	1.533
2000	Port Elizabeth, South Africa	30	1.478
2000	Jeju, South Korea *		777
2002	Nice, France	50	2.069
2002	Frankfurt, Germany	100	2.220
2002	Wisconsin, United States	65	2.244
2003	Coeur d'Alene, United States	50	2.188
2004	Busselton, Australia	40	1.163
2005	Arizona, United States	65	2.565
2005	Bolton, United Kingdom	50	1.051
2007	Louisville, United States	50	2.276
2009	Cozumel, Mexico	50	2.135
2010	Regensburg, Germany	50	1.816
2010	St. George, United States	50	1.310
2011	Texas, United States	50	2.001
2011	Wales, United Kingdom	50	1.134
2012	Melbourne, Australia	75	-
2012	New York, United States	75	-
2012	Mont-Tremblant, Canada	50	-
2012	Kalmar, Sweden	50	-

* will not take place in 2012

Slovenia (SLO), Hungary (HUN), Croatia (CRO) and Slovakia (SVK) accounted for 365 (1.7%). The number of women and men finishers for countries with more than 100 participants in total is shown in Figure 3. For both women and men, most of the finishers originated from Switzerland (SUI), followed by Germany (GER), Great Britain (GBR), France (FRA) and Italy (ITA).

Figure 4 demonstrates the change of participants across the years regarding country of origin. Linear regression was used to determine whether nations showed a significant change in the number of participants over time or not. Overall, we found a significant increase in every country. Great Britain (GBR) showed the greatest increase with 40 triathletes in 2002 to the maximum of 415 in 2010. During the 17-year period, 29 winners originated from Europe (85.3%), three from Australia, New Zealand and Polynesia (8.8%) and two from North-America (5.9%). Twenty-one winners

(i.e. eight women and 13 men) originated from Switzerland (SUI) (61.8%), six (i.e. four women and two men) from Germany (GER) (17.7%), two men from Hungary (HUN), two women from Australia (AUS) (5.9%) one woman each from New Zealand (NZL), United States (USA) and Canada (CAN) (2.9%).

Performance trends

The mean total race time of the overall top ten triathletes was 606 ± 24.3 min for women and 527.9 ± 10.3 min for men. The general development of performance was analysed by linear regression. Between 1995 and 2011, the top ten women and men overall significantly improved their total race time (Figure 5). Figure 6 shows the total race times for the top ten women and men triathletes for the most representative countries. The fastest women triathletes originated from Switzerland (658.2 ± 53.1 min) followed by athletes from Germany (651.5 ± 26.6 min), the United States of America and Great Britain. For men, the fastest top ten triathletes originated from Switzerland (547.2 ± 17.5 min), followed by athletes from Germany (555.1 ± 13.9 min), France (584.9 ± 31.9 min) and Belgium.

Figure 7 shows the changes in performances across the years of the fastest athletes for nations with more than

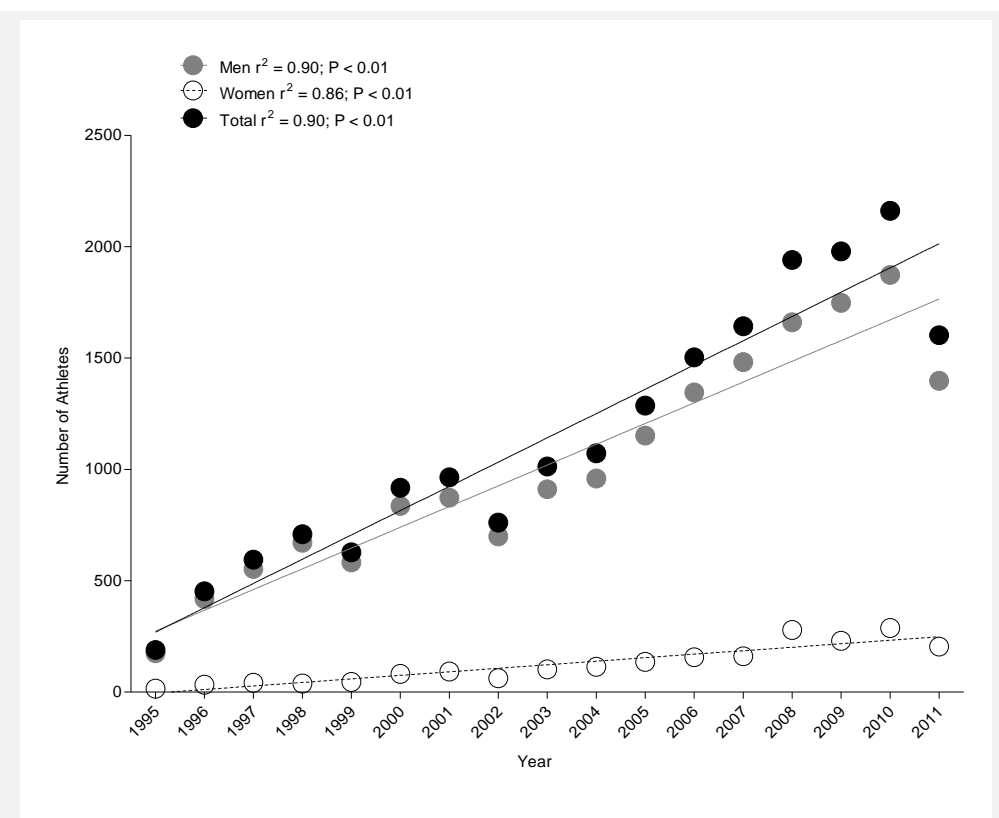


Figure 1. Changes in the annual numbers of women, men and overall finishers in 'Ironman Switzerland' between 1995 and 2011.

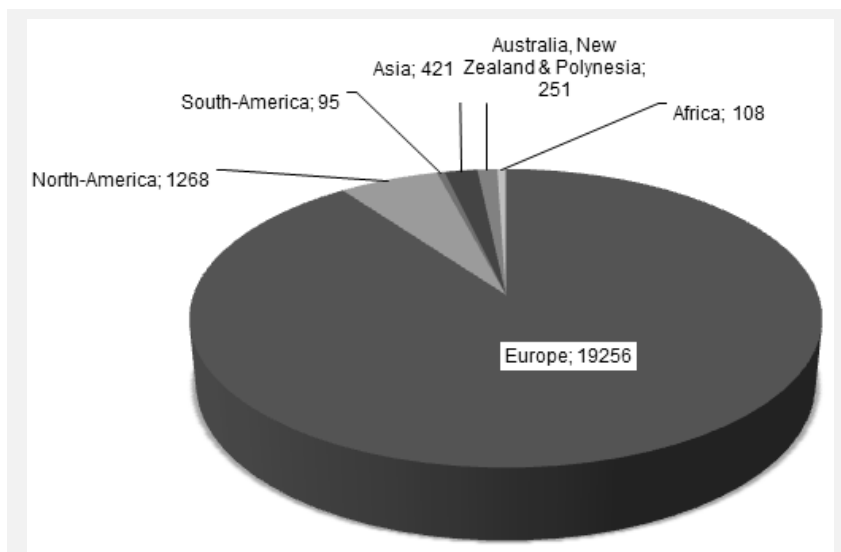


Figure 2. Total number of participants per continent in 'Ironman Switzerland' between 1995 and 2011.

500 participants in total. For women, the Swiss triathletes improved their total performance over the years in contrast to the German athletes. For men, the greatest rates of improvement were observed for the British athletes, followed by triathletes from the United States of America, Italy and Switzerland.

Discussion

The aim of the study was to analyse the participation and performance trends at the 'Ironman Switzerland' regarding the nationality of the triathletes between the

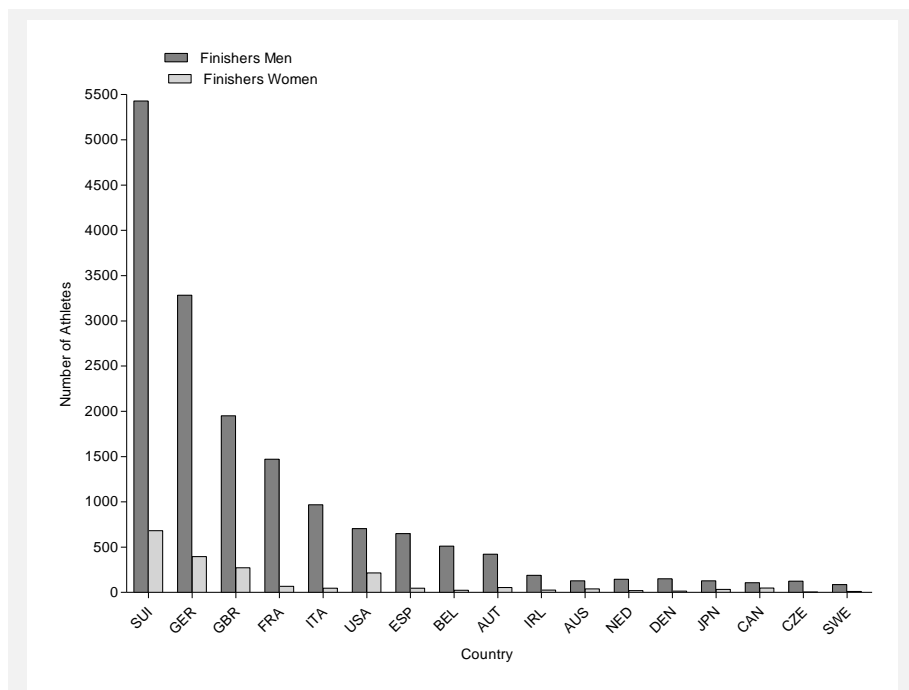


Figure 3. Number of women and men finishers for the countries with > 100 participants in total.

first edition in 1995 and 2011. The major finding of this study was that 90% of the participants were originating from Europe and 66.6% from Switzerland and neighbouring countries such as Germany, France, Austria, Fürstentum Liechtenstein and Italy. The dominating nations regarding participation and performance were Switzerland and Germany. Indeed, these countries presented the highest amount of participants (*i.e.* Switzerland 31.9% and Germany 18.9%), most of the race winners (*i.e.* Switzerland 21 and Germany 6) and the fastest mean total race times for both sexes.

Participation trends

The ‘Ironman Switzerland’ showed an increase of participants since 1995 until 2010 with an unexpected decline in 2011. Endurance and ultra-endurance sports are experiencing a great increase in popularity with growing numbers of participants all over the world (Hoffman et al. 2010; Lepers 2008). Not at least because of the established positive effects on expectation of life and health in general (Jackson et al. 2009; Kodama et al. 2009; Lee et al. 2010), which might be reflected in the increase of master triathletes in ‘Ironman Hawaii’ in the last 25 years (Lepers et al. 2012) and also in ‘Ironman Switzerland’ (Stiefel et al. 2012). This growing interest has been shown for the

‘Ironman Hawaii’ (Lepers 2008) as well as for other endurance events such as marathon running (Burfoot 2007), the 161-km ultramarathons in North America (Hoffman et al. 2010) and the ultra-triathlons such as Double, Triple and Deca Iron ultra-triathlons (Knechtle et al. 2011c; Rüst et al. 2012a). This trend remains unchanged for ‘Ironman Switzerland’. The decline of participants in 2011 might be associated with the amount and constellation of qualifying events for the ‘Ironman World Championship’ in Hawaii (Table 1). Already six qualifying races were held every year in Europe from May to July. Moreover, two new qualifying events were launched in Germany (Regensburg) and Wales (Pembrokeshire) in 2010 and 2011, respectively. Currently, five official qualifying events take place in the radius of 450 km around Zurich in less than a month, which makes central Europe the region with the highest concentration of qualifying events in the world.

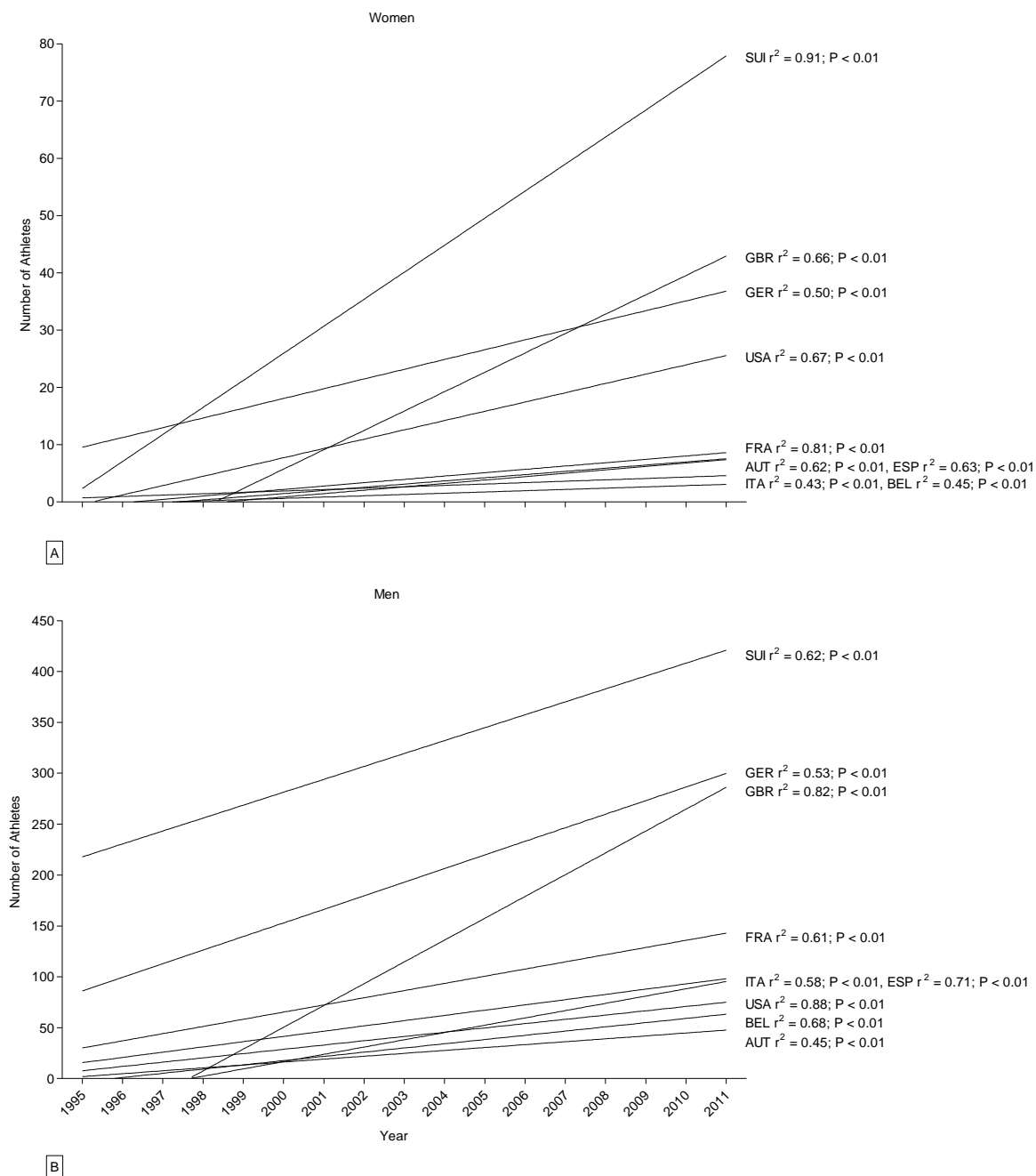


Figure 4. Changes in numbers of participants for women (Panel A) and men (Panel B) of countries with more than 500 participants in total. In case of a significant change over time, r^2 - and P-values are inserted.

Origin of athletes

According to our hypothesis, most of the participants came from Switzerland and its neighbouring countries. Considering the lack of existing data regarding epidemiology in 'Ironman' triathlon, we can only speculate about the reasons for our findings. Reasons for triathletes to participate in different qualifying races might primarily be due to the travel distance. This includes the available time as well as associated expenses for the journey itself and accommodation. Additionally, the stress of long distance travels could possibly result in worse performance, whereas a short

travel distance and familiarity with the climate and the terrain might lead to better performances. Secondly, the amount of qualifying slots for the World Championships (*i.e.* for the best age groupers) and the offered prize money (*i.e.* for the elite triathletes) might play a role in the triathlete's decision. The interest in taking part in new or different race courses might be a motivation to choose different locations. We assume that reasons to prefer Switzerland to race primarily were the location in central Europe given the short travel distance for most of the triathletes. For the Swiss triathletes, prestige and patriotism might have been other motivations to take part in the race in their home

country. Finally, Switzerland used to offer 75 qualification slots for the World Championships, but was recently reduced to 50 as most of the other qualifying races.

Another important finding was that only 14% of the participating triathletes attended from European countries without a qualifying race such as Italy, the Netherlands, Belgium, Ireland, Denmark and Greece. Keeping in mind that most of the participants prefer to travel short distances and two thirds came from neighbouring countries to Switzerland, which mostly hold their own qualifying race (*i.e.* France, Germany and Austria), this finding is not very surprising. However, it underlines the presumption that most of the European countries, where triathlon is popular, hold their own qualifying race with most of the contestants participating in their home country. Surprisingly, triathletes from Italy represented only 5.3% of the field. Presumably, Italian triathletes prefer the races in Austria, Germany or France, which are either neighbouring countries or within a reachable distance.

The other interesting finding was that participants from East European countries such as the Czech Republic, Poland, Slovenia, Hungary, Croatia and Slovakia only accounted for almost two percent of the total field. Multiple factors probably contribute to this finding with the extremely high costs of the triathlon sport itself playing a major role. Hoffman and Fogard (2012) recently analysed the characteristics of ultra-marathon runners and showed that the average athlete is male, about 45 years of age, married and owns a university degree. These characteristics might be as well applicable to 'Ironman' triathletes. A large scale market research report from the US stated that the average yearly income of a triathlete from the US is 126,000 US-Dollars

(www.usatriathlon.org/news/articles/2009/04/passion-for-triathlon-growing-according-to-new-participant-study.aspx). According to the World Bank, the mean yearly income in Slovenia, which accounts for the highest income in East Europe, is 23,860 US-Dollars in comparison to 47,140 US-Dollars in the United States (www.worldbank.org), which highlights that triathlon is an expensive sport for wealthy athletes. This presumption is supported by a survey of the European Triathlon Union in 2010, which showed that elite triathlon is very expensive, mostly supported by the government and not affordable for many of the East European countries

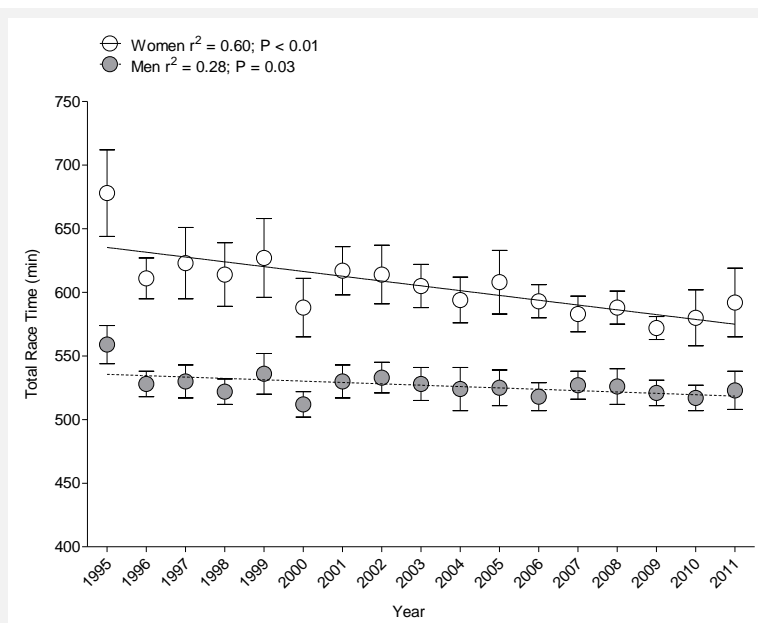


Figure 5. Changes in total race time for the overall top ten women and men per year.

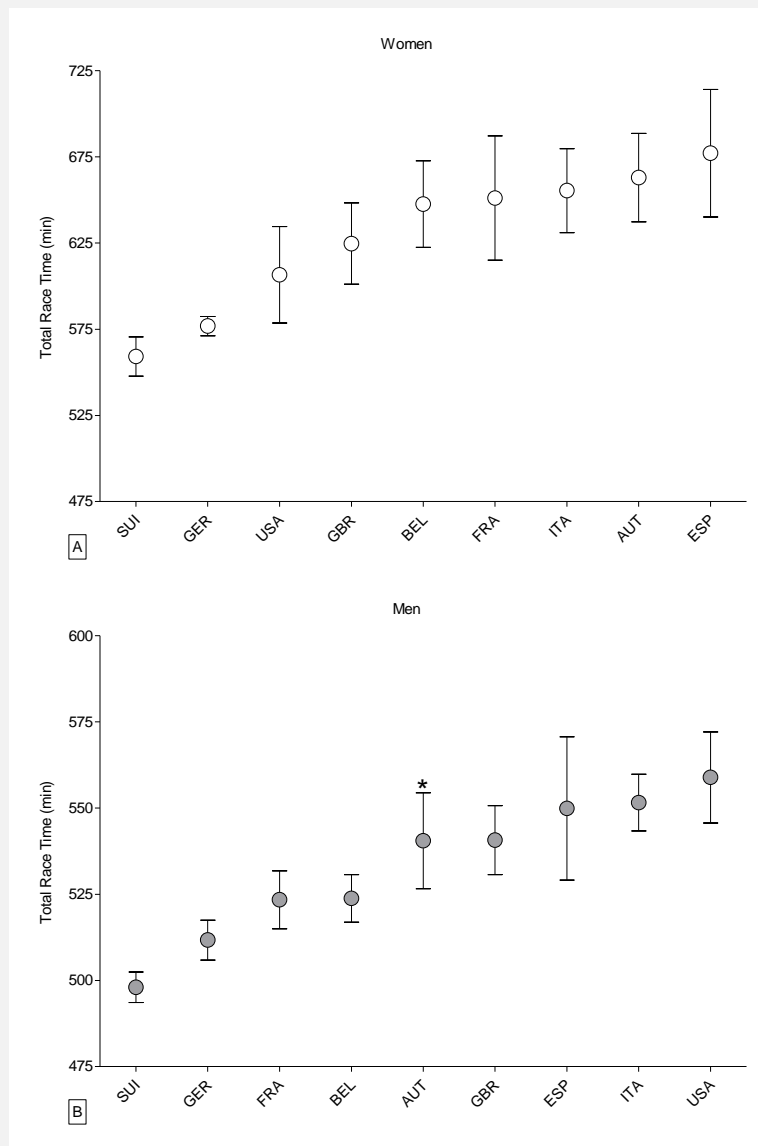


Figure 6. Mean total race time \pm SD of the top ten women (Panel A) and men (Panel B) triathletes per country. The countries are arranged by mean total race time. An asterisk (*) indicates values that were significantly different from the previous one.

(<http://etu.triathlon.org/en/downloads>). Furthermore, apart from financial aspects, environmental and social factors might cause other limitations for a growth in popularity, for instance, having only a small number of public accessible swimming pools or tarmac roads considering cycling. The situation in East Europe might be as well transferable to other regions in the world

such as Africa, South and Middle America and Asia. In addition to the great distance these speculations could partly explain the low numbers of participants at the 'Ironman Switzerland' from these continents. In contrast, the United States, representing a wealthy country, where triathlon is popular, shows a relative high percentage (4.8%) of participants despite the great

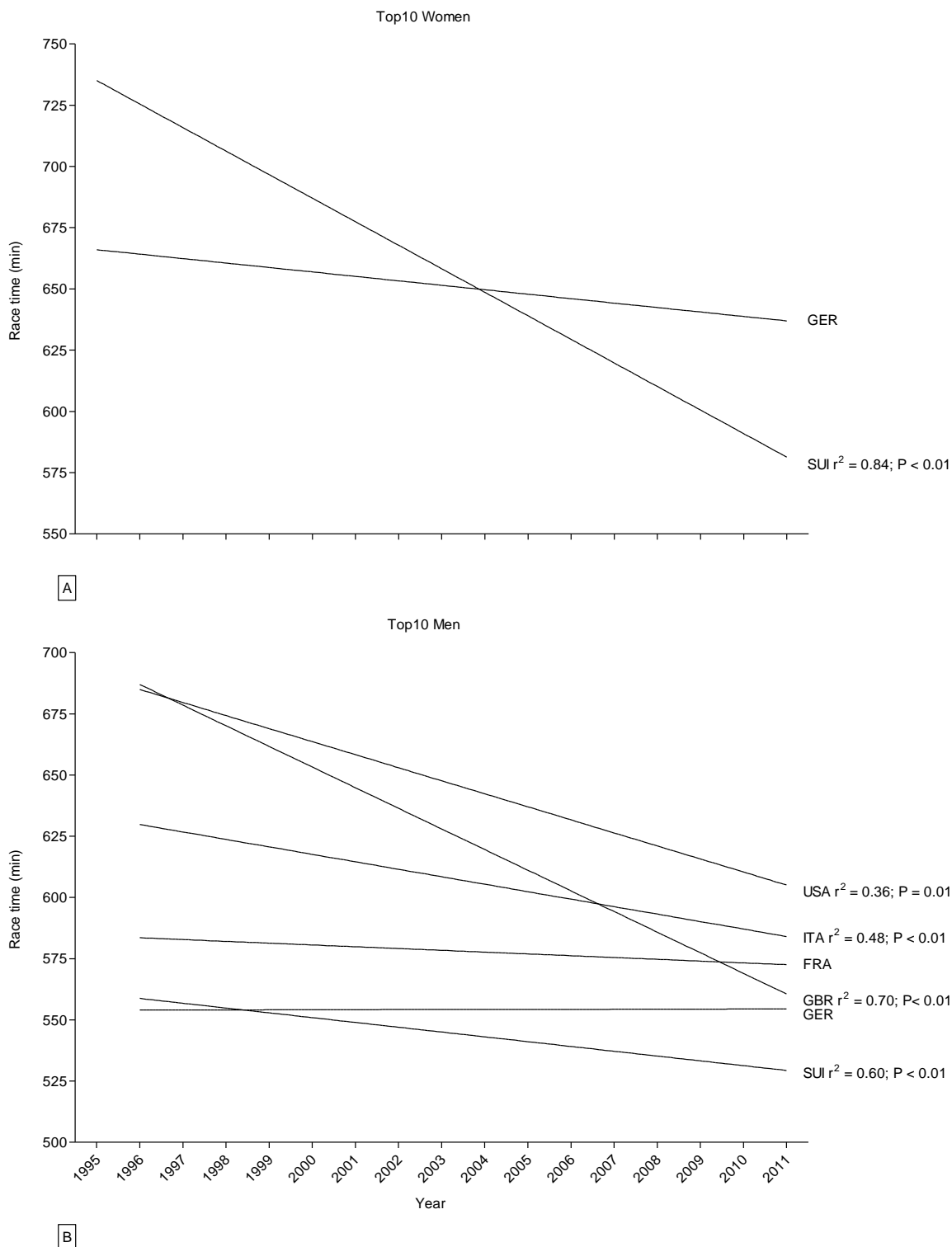


Figure 7. Changes across the years in total race time of the top ten women (Panel A) and men (Panel B) triathletes per country. In case of a significant change, r^2 - and P-values are inserted.

distance.

A further important and not expected finding was that athletes from Great Britain showed the highest increase in participants and accounted for the third largest group of athletes, behind Switzerland and Germany. This is even more remarkable considering that they hold their own qualifying race since 2005 with the 'Ironman UK' and having a neighbouring event in Wales since 2011. Additionally, the United States presented a relatively high amount of triathletes (4.8%). A possible explanation, apart from the ones mentioned above, for triathletes from Great Britain to prefer Switzerland to race could be the novelty of the races in England and Wales since 2005 and 2011, respectively, in contrast to the well-established race in Zurich. Furthermore, Switzerland is a popular vacation destination, with Zurich itself ranking under the world's best places to visit (http://travel.usnews.com/Rankings/Worlds_Best_Vacations), which might play a certain role in the considerations of athletes from Great Britain and the US.

Performance trends

In accordance with our hypothesis, European triathletes from Switzerland and Germany attained the fastest total race times for both gender regarding the top ten athletes. Ranking behind amongst others were athletes from France, Belgium, Austria, Great Britain, Spain, Italy and the United States. Furthermore, athletes of both gender showed a tendency to improve their performance, which reflects the trend of the overall top ten triathletes. Surprisingly, the German triathletes did not improve their performance.

The improvement of performance in the overall top ten and most of the individual countries is a phenomenon that is often found in relative new sports such as 'Ironman' triathlon (Desgorces et al. 2008; Lepers 2008). At 'Ironman Switzerland' it occurs in particular for triathletes from Switzerland, who started ranking second to Germany's athletes, but improved their performance highly significantly. Currently, Swiss triathletes are the best performers in 'Ironman Switzerland' and the gap between Swiss athletes and the following countries seems to grow. This might be either due to the fact that 'Ironman Switzerland' is becoming a highly prestigious race for Swiss athletes or Switzerland in general is becoming one of the best performing nations in triathlon. However, in addition to the Swiss athletes' short travel distance, we also have to consider their familiarity with the climate and the terrain and account them as cofactors for a better performance.

In contrast, Germany's triathletes showed no significant improvement of performance for both gender. German athletes still rank second for both gender, but athletes from France, Spain, Great Britain, Italy, Austria and Belgium might be able to outrun the German athletes in the next years. Possible explanations for this development might be amongst others an earlier interest in the sport in Germany as

well as a different approach to the race. After the 'Ironman' triathlon was introduced in the US in 1978 (Lepers 2008), the sport experienced growing popularity preferably in the northern parts of Europe in the early 1980's before the southern parts and Switzerland

(www.swisstriathlon.ch/desktopdefault.aspx/tabid-36/207_read-1100). Consequently, with an earlier interest in the sport, athletes from Germany performed better until more athletes from other countries engaged in the races and improved their performance. This agrees with our finding of Germany's athletes performing best in the first years of the 'Ironman Switzerland', but other countries, starting ranked behind Germany, catching up due to constant improvement of their performance.

Another possible explanation might be a different approach of German athletes to the race. With the triathlon in Germany experiencing an early growth in popularity, the European Championships were held in Roth, Germany. At the same time, there was no other official 'Ironman' event held in Europe until 1992, when the 'Ironman Lanzarote' in Spain took place for the first time. This implies that many elite athletes from Germany and different European countries participated in the European Championships in Roth and the mean recreational athlete from Germany had to participate in different races, because of the limited number of participants in the European Championships. With Lanzarote still being distant from central Europe, the 'Ironman Switzerland' since 1997 and the 'Ironman Austria' since 1998 offered two alternatives for German athletes and could have led to less ambitious athletes participating in these qualifying races.

Before we mentioned unexpected high numbers of participants from Great Britain and the United States and guessed that taking part in the 'Ironman Switzerland' could be seen as a part of a holiday for these athletes. However, the performance analysis of British triathletes showed that the men top ten athletes ranked among the best nations with a tendency to improvement. This finding makes the assumed explanation less likely for British men athletes, but it might still be applicable to men triathletes from the United States, who presented the slowest total race times of the analysed nations.

Limitations and implications for future research

The 'Ironman' is a relative new endurance sport with the first race held in Hawaii in 1978 and the first 'Ironman Switzerland' in 1995, which limits the available amount of data for adequate statistics. Therefore we could not provide the intended comparison of performances from European athletes to athletes from other continents. Regarding future studies, the comparability of the athletes' performances to other triathlon races might be limited due to the differing race courses and weather conditions (Lepers 2008). Additionally, the comparison to the World Championships might be limited due to the fact that athletes have to qualify for the event in Hawaii and

therefore the amount of women and elite athletes in this race is probably a lot higher than in a qualifying race. Finally, we have to bear in mind that the qualifying races for the World Championships of Triathlon are mass-participation events, where most of the participants are rather recreational than elite athletes. These recreational athletes, in contrast to elite athletes, firstly cannot spend as much time on preparation for such a race, which includes travelling time as well, and secondly do not usually have the chance to train in different climate zones or weather conditions. Consequently, most of the recreational athletes will have difficulties to adjust to new climate or weather conditions as well as new terrains, such as the mountainous region in Switzerland, which possibly would lead to worse performance. In future studies these factors should be either considered as confounders or predictors in their own right regarding their impact on performance, when analysing performances in mass-participation events.

Conclusion

To summarize, most of the participants in 'Ironman Switzerland' originated from Switzerland and its neighbouring countries such as France, Germany, Italy and Austria. Few athletes attended from European countries without a qualifying race and from East European countries. Apart from the United States, competitors from non-European countries (e.g. Canada, Australia, South-Africa and Japan) represented a low percentage of the participants. Triathletes from Switzerland and Germany dominated the race, but athletes from other European countries such as France, Spain, Italy, Belgium, Austria and Great Britain might outrun the German athletes in the near future. Reasons for Switzerland's special position as the best performing nation could be either found in the 'Ironman Switzerland' being a highly prestigious race for these athletes, their advantage of being familiar with the weather and the terrain, or in a general trend with Switzerland presenting the best triathletes in the world. Additional performance analyses regarding the nationality of the participants in the qualifying races for the 'Ironman World Championship' in Hawaii and the 'Ironman World Championship' itself would be interesting in order to identify the countries with the best performing long-distance triathletes in the world.

References

1. Burfoot A (2007) The history of the marathon : 1976-present. *Sports Medicine* 37(4-5): 284-287.
2. Burns J, Keenan AM, Redmond AC (2003) Factors associated with triathlon-related overuse injuries. *The Journal of Orthopaedic and Sports Physical Therapy* 33(4):177-184.
3. Caló MC, Vona G (2008) Gene polymorphisms and elite athletic performance. *Journal of Anthropological Sciences* 86:113-131.
4. Desgorces FD, Berthelot G, El Helou N, Thibault V, Guillaume M, Tafflet M, Hermine O, Toussaint JF (2008) From Oxford to Hawaii ecophysiological barriers limit human progression in ten sport monuments. *PLoS One* 3(11):e3653.

5. Eichenberger E, Knechtle B, Knechtle P, Rüst CA, Rosemann T, Lepers R (2012) No gender difference in peak performance in ultra-endurance swimming performance – Analysis of the 'Zurich 12-h Swim' from 1996 to 2010. *Chinese Journal of Physiology*, in press
6. Egermann M, Brocai D, Lill CA, Schmitt H (2003) Analysis of injuries in long-distance triathletes. *International Journal of Sports Medicine* 24(4):271-276.
7. Eynon N, Ruiz JR, Oliveira J, Duarte JA, Birk R, Lucia A (2011) Genes and elite athletes: a roadmap for future research. *The Journal of Physiology* 589(Pt 13):3063-3070.
8. Harriss DJ, Atkinson G (2011) Update – Ethical Standards in Sport and Exercise Science. *International Journal of Sports Medicine* 32(11): 819-821.
9. Haupt S, Knechtle B, Knechtle P, Rüst CA, Rosemann T, Lepers R (2012) The age-related performance decline in ultra-endurance mountain biking. *Research in Sports Medicine*, in press
10. Hoffman MD, Fogard K (2012) Demographic characteristics of 161-km ultramarathon runners. *Research in Sports Medicine* 20(1):59-69.
11. Hoffman MD, Ong JC, Wang G (2010) Historical analysis of participation in 161 km ultramarathons in North America. *The International Journal of the History of Sport*. 27(11):1877-1891.
12. Jackson AS, Sui X, Hébert JR, Church TS, Blair SN (2009) Role of lifestyle and aging on the longitudinal change in cardiorespiratory fitness. *Archives of Internal Medicine* 26;169(19):1781-1787.
13. Knechtle B, Knechtle P, Andonie JL, Kohler G (2007) Influence of anthropometry on race performance in extreme endurance triathletes: World Challenge Deca Iron Triathlon 2006. *British Journal of Sports Medicine* 41(10):644-648.
14. Knechtle B, Knechtle P, Rosemann T (2011a) Upper body skinfold thickness is related to race performance in male Ironman triathletes. *International Journal of Sports Medicine* 32(1):20-27.
15. Knechtle B, Knechtle P, Rosemann T, Senn O (2011b) Personal best time, not anthropometry or training volume, is associated with total race time in a triple iron triathlon. *Journal of Strength and Conditioning Research* 25(4):1142-1150.
16. Knechtle B, Knechtle P, Lepers R (2011c) Participation and performance trends in ultra-triathlons from 1985 to 2009. *Scandinavian Journal of Medicine and Science in Sports* 21(6):e82-e90.
17. Knechtle B, Rüst CA, Rosemann T, Lepers R (2012) Age-related changes in 100-km ultra-marathon running performance. *Age (Dordrecht, Netherlands)* 34(4):1033-45.
18. Knechtle B, Wirth A, Baumann B, Knechtle P, Rosemann T (2010a) Personal best time, percent body fat, and training are differently associated with race time for male and female ironman triathletes. *Research Quarterly for Exercise and Sport* 81(1):62-68.
19. Knechtle B, Wirth A, Baumann B, Knechtle P, Rosemann T, Oliver S (2010b) Differential correlations between anthropometry, training volume, and performance in male and female Ironman triathletes. *Journal of Strength and Conditioning Research* 24(10):2785-2793.
20. Kodama S, Saito K, Tanaka S, Maki M, Yachi Y, Asumi M, Sugawara A, Totsuka K, Shimano H, Ohashi Y, Yamada N, Sone H. (2009) Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and

- cardiovascular events in healthy men and women: a meta-analysis. *JAMA* 301(19):2024-2035.
21. Larsen HB (2003) Kenyan dominance in distance running. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 136(1):161-170.
 22. Lee DC, Artero EG, Sui X, Blair SN (2010) Mortality trends in the general population: the importance of cardiorespiratory fitness. *Journal of Psychopharmacology* 24(4 Suppl):27-35.
 23. Lepers R (2008) Analysis of Hawaii ironman performances in elite triathletes from 1981 to 2007. *Medicine and Science in Sports and Exercise* 40(10):1828-1834.
 24. Lepers R, Maffiuletti NA (2011) Age and gender interactions in ultraendurance performance: insight from the triathlon. *Medicine and Science in Sports and Exercise* 43(1):134-139.
 25. Lepers R, Rüst CA, Stapley PJ, Knechtle B (2012) Relative improvements in endurance performance with age: evidence from 25 years of Hawaii Ironman racing. Age (Dordrecht, Netherlands) 2012 Feb 26. [Epub ahead of print].
 26. Onywera VO, Scott RA, Boit MK, Pitsiladis YP (2006) Demographic characteristics of elite Kenyan endurance runners. *Journal of Sports Sciences* 24(4):415-422.
 27. Onywera VO (2009) East African runners: their genetics, lifestyle and athletic prowess. *Medicine and Sports Science* 54:102-109.
 28. Rüst CA, Knechtle B, Knechtle P, Rosemann T, Lepers R, Onywera V (2012a) European athletes dominate performances in Double Iron ultra-triathlons – a retrospective data analysis from 1985 to 2010. *European Journal of Sport Science*, in press.
 29. Rüst CA, Knechtle B, Knechtle P, Pfeifer S, Rosemann T, Lepers R, Senn O (2012b) Gender difference and age-related changes in performance at the long distance duathlon World Championships. *Journal of Strength and Conditioning Research*, Research 2012 Mar 24. [Epub ahead of print].
 30. Scott RA, Fuku N, Onywera VO, Boit M, Wilson RH, Tanaka M, H Goodwin W, Pitsiladis YP (2009) Mitochondrial haplogroups associated with elite Kenyan athlete status. *Medicine and Science in Sports and Exercise* 41(1):123-128.
 31. Scott RA, Georgiades E, Wilson RH, Goodwin WH, Wolde B, Pitsiladis YP (2003) Demographic characteristics of elite Ethiopian endurance runners. *Medicine and Science in Sports and Exercise* 35(10):1727-1732.
 32. Scott RA, Pitsiladis YP (2007) Genotypes and distance running : clues from Africa. *Sports Medicine* 37(4-5):424-427.
 33. Stiefel M, Knechtle B, Lepers R (2012) Master triathletes have not reached limits in their Ironman triathlon performance. *Scandinavian Journal of Medicine and Science in Sports*. doi: 10.1111/j.1600-0838.2012.01473.x. [Epub ahead of print].
 34. Strock GA, Cottrell ER, Lohman JM (2006) Triathlon. *Physical Medicine and Rehabilitation Clinics of North America* 17(3):553-564.
 35. Zaryski C, Smith DJ (2005) Training principles and issues for ultra-endurance athletes. *Current Sports Medicine Reports* 4(3):165-170.