Age and Gender Interactions in Ultraendurance Performance: Insight from the Triathlon

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ABSTRACT

LEPERS, R. and N. A. MAFFIULETTI. Age and Gender Interactions in Ultraendurance Performance: Insight from the Triathlon. *Med. Sci. Sports Exerc.*, Vol. 43, No. 1, pp. 134–139, 2011. **Purpose**: The purposes of this study were (i) to investigate the effect of age on gender difference in Hawaii Ironman triathlon performance time and (ii) to compare the gender difference among swimming (3.8 km), cycling (180 km), and running (42 km) performances as a function of age. **Methods**: Gender difference in performance times and estimated power output in the three modes of locomotion were analyzed for the top 10 men and women amateur triathletes between the ages of 18 and 64 yr for three consecutive years (2006–2008). **Results**: The gender difference in total performance time was stable until 55 yr and then significantly increased. Mean gender difference in performance time was significantly (P < 0.01) smaller for swimming (mean ± 95% confidence interval = 12.1% ± 1.9%) compared with cycling (15.4% ± 0.7%) and running (18.2% ± 1.3%). In contrast, mean gender difference in cycling estimated power output (38.6% ± 1.1%) was significantly (P < 0.01) greater compared with swimming (27.5% ± 3.8%) and running (32.6% ± 0.7%). **Conclusions**: This cross-sectional study provides evidence that gender difference in ultraendurance performance such as an Ironman triathlon was stable until 55 yr and then increased thereafter and differed between the locomotion modes. Further studies examining the changes in training volume and physiological characteristics with advanced age for men and women are required to better understand the age-associated changes in ultraendurance performance. **Key Words:** SWIMMING, CYCLING, RUNNING, ULTRAENDURANCE EXERCISE, GENDER DIFFERENCE, AGING

The gender difference in endurance (events lasting <2–3 h) and ultraendurance (events lasting >3 h) performance has attracted considerable attention during the last 30 yr. The majority of studies on gender difference have focused on running performance (e.g., Coast et al. [4], Cheuvront et al. [3], Hoffman [6,7], Leyk et al. [16], Sparkling et al. [25]), but fewer have analyzed the gender difference in swimming (27,29), cycling (23), or triathlon performance (14,28). The ~10%–15% sex gaps in endurance performance seem to be biological in origin; because men possess a greater aerobic capacity and muscular strength, the gap in endurance performances between men and women is unlikely to narrow naturally (4).

Knowing that the physiological (e.g., muscle strength, oxygen-carrying capacity) and morphological (e.g., percentage of body fat, muscle mass) functional characteristics change with advancing age, gender difference in endurance performance may also change with advancing age. Concerning the gender-specific differences in loss of muscle mass with age (sarcopenia), some studies have shown that elderly women may lose it more rapidly than their male counterparts (20,22), although this is not a general finding. Few studies, however, have investigated the combined interaction of age and gender on endurance performance. For example, the increase in 10-km running time with advancing age has been found to be greater in women compared with men (30). Similarly, Tanaka and Seals (29) reported that the rate of decline in swimming performance with age was greater in women than in men. Taken as a whole, these findings suggest the possibility of an increased sex gap in endurance performance with advanced age.

Age and gender interaction in endurance performance could also be influenced by the type and duration of the physical task performed. Changes in running performance do not necessarily reflect aging and gender interactions in other types of endurance activities. In fact, Tanaka and Seal (29) showed that endurance in a 1500-m swimming performance decreased with age in men and women, but the pattern of decline was somewhat different from that observed with long-distance running (10,30). Indeed, the magnitude of overall reduction in swimming performance with advancing age seemed to be smaller than that observed in running performance. However, these results obtained from different populations limit the interpretation of these findings. The effect of age on gender difference in endurance and ultraendurance performances remains to be clarified for the different modes of locomotion (e.g., swimming, cycling, and running).

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In this regard, triathlon involving swimming, cycling, and running represents an intriguing alternative model to analyze the age and gender interaction in endurance performance because gender difference can be analyzed in the same subjects collectively and also for the three disciplines separately (2,13,14). However, it should be pointed out that because of the fatigue accumulated during the previous disciplines, running performance in a triathlon cannot be compared with running alone. A previous study conducted on elite triathletes at the Hawaii Ironman triathlon showed that the mean gender difference tended to be smaller in swimming compared with that in cycling and running (14). However, this study focused only on the top 10 men and women overall finishers and did not provide a complete representation of gender difference with age.

Accordingly, the aims of the present study were 1) to examine the effect of age on gender difference in the Ironman triathlon total time and 2) to compare the gender difference as a function of age among swimming, cycling, and running. To achieve these aims, a retrospective analysis of top amateur performance times aged from 18 to 65 yr was performed at the Hawaii Ironman triathlon, which is the top race in the field of long-distance triathlon (14). We anticipated that gender differences in total time performance would increase with advancing age and that gender difference in performance time would be lower in swimming compared with that in cycling and running.

METHODS

Approval for the project was obtained from the Burgundy University Committee on Human Research. This study involved the analysis of publicly available data, so content was waived. Age and time performances data for all triathletes completing the races were obtained through the Ironman Corporation's Web site: http://ironman.com/events/ironman. The Hawaii Ironman triathlon (3.8-km swim, 180-km cycle, and 42-km run) has been held each year since 1982 in Kailua-Kona (Big Island, HI). The Hawaii Ironman triathlon is the last in a series of nearly 25 Ironman triathlons held in the world that serve as qualifying races. Only the best amateur triathletes in their age group and elite triathletes can participate in the final in Hawaii that is considered as the Ironman World Championship for both amateur and elite triathletes.

Averaged swimming, cycling, running, and overall time performances of the top 10 amateur of nine age groups for women and men, respectively, were analyzed for three consecutive Hawaii Ironman races in 2006, 2007, and 2008. We focused our attention on these 3 yr because we thought that it would represent a better insight into the current performance. The Ironman age groups (http://ironman.com/events/ironman) distinguish the categories as follows: 18–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, and 60–64 yr.

The performances of 30 triathletes per age group (i.e., the top 10 of each age group in 2006, 2007, and 2008) were considered. Because one-way ANOVA showed no significant difference for the top 10 of the best performing age group among 2006 (women = 10 h 14 min 37 s ± 12 min 50 s, men = 9 h 4 min 1 s ± 8 min 20 s), 2007 (women = 10 h 22 min 10 s ± 10 min 18 s, men = 9 h 10 min 34 s ± 6 min 11 s), and 2008 (women = 10 h 17 min 16 s ± 12 min 56 s, men = 9 h 11 min 57 s ± 10 min 6 s), data were pooled together.

The magnitude of gender difference was examined by calculating the percent difference for the average totals of swimming, cycling, and running times between the top men versus the top women of each age group. Because of the nonlinear relation between speed and power output from air or water resistance (27), percent differences in time do not equate to percent differences in power output. Therefore, we estimated the percent difference in power output between the men and women for each discipline according to Lepers (14). Briefly, for swimming, the mechanical power (P) depends on the third power of velocity (V); according to the model proposed by Stefani (27), the swimming power ratio between men (m) and women (w) is as follows:

$$P_w/P_m = 0.91(V_w/V_m)^3 \quad [1]$$

Similarly, for cycling, the mechanical power also depends on the third power of velocity; assuming level terrain, no wind, and a negligible contribution of rolling resistance to total power demand, the cycling power ratio between men and women is as follows:

$$P_w/P_m = 0.93(V_w/V_m)^3 \quad [2]$$

For running, the mechanical power depends on the velocity and on the body mass (27); accordingly, running power ratio between men and women is as follows:

$$P_w/P_m = 0.79(V_w/V_m) \quad [3]$$

Finally, the percentage difference in estimated power between women and men was calculated as $100(1-P_w/P_m)$ for the three disciplines.

The percentage difference between the man and woman in swimming, cycling, running, and total event performance times and in estimated power outputs for each of the top 10 places and for each year in each age group was determined. One-way ANOVA was used to compare gender difference in total time across ages. Two-way ANOVA (age group × mode of locomotion) with repeated measures on locomotion mode were used to compare gender difference in time and power output among swimming, cycling, and running across ages. The Tukey *post hoc* analyses were used to test differences within the ANOVA when appropriate. A significance level of $P < 0.05$ was used to identify statistical significance.

RESULTS

The swimming, cycling, running, and total performance times of the 10 top men and women are presented in Figure 1. Compared with the fastest men's age groups (30–34 or 35–39 yr), time performance of the slowest men's age group (60–64 yr) was longer for total event (27%), swimming

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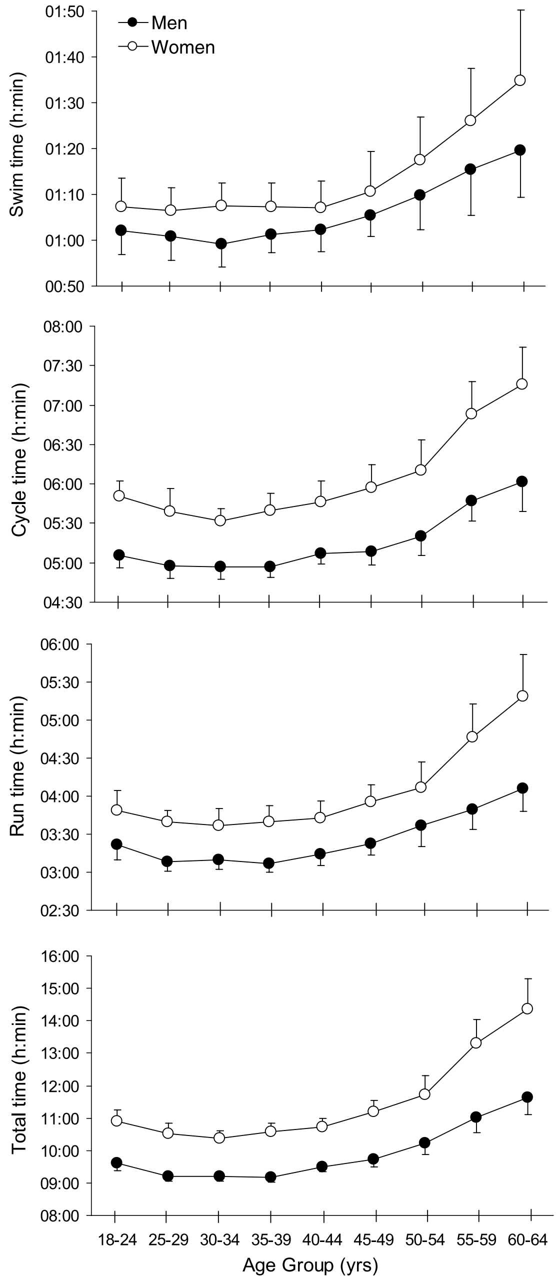

FIGURE 1—Swimming, cycling, running, and total performance times for the top 10 men and women in each age group at the Hawaii Ironman triathlon (2006, 2007, and 2008 pooled data). Values are mean ± SD.

(30%), cycling (22%), and running (32%). Compared with the fastest women's age groups (25–29 or 30–34 yr), time performance of the slowest women's age group (60–64 yr) was longer for total event (38%), swimming (43%), cycling (31%), and running (47%). For both men and women, SD (indicating within-group variability) for total event and for the three disciplines increased considerably with advancing age, particularly for women.

Figure 2 shows that gender differences in total event time were affected by age (F = 78.8, P < 0.001). Gender difference for age groups 55–59 and 60–64 yr were significantly (P < 0.01) greater compared with that for younger age groups, and gender difference for age group 55–59 yr was significantly (P < 0.05) lower than that for age group 60–64 yr.

There was no significant age group × locomotion mode interaction for gender difference in performance time (F = 1.02, P = 0.42). Independent of age, gender differences

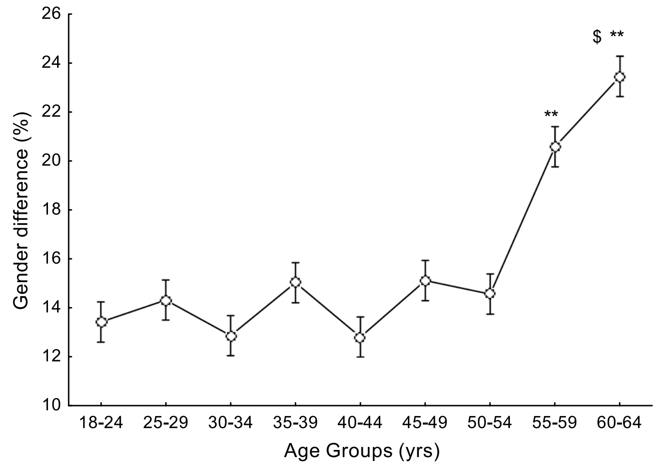

FIGURE 2—Averaged gender difference in time for total event at the Hawaii Ironman Triathlon (2006, 2007, and 2008 pool data). Values are means ± 95% confidence interval. **Significantly different from all age groups from 20–24 to 50–55 yr, P < 0.01. $Significantly different from age group 55–59 yr, P < 0.05.

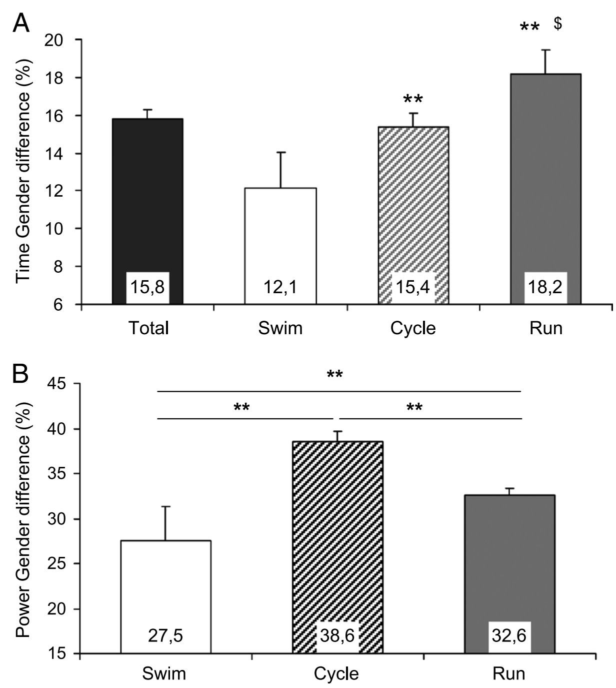

FIGURE 3—A, Averaged gender difference in time performance for swimming, cycling, running, and total event across all age groups (18–24 to 60–64 yr). Values are means ± 95% confidence interval. $Significantly different from cycle, P < 0.05. **Significantly different from swim, P < 0.01. B, Averaged gender difference in estimated power output for swimming, cycling, and running across all age groups (18–24 to 60–64 yr). Values are means ± 95% confidence interval. **Significant difference, P < 0.01.

in time differed between the locomotion modes ($F = 16.17$, $P < 0.001$). Gender difference in swimming time was significantly ($P < 0.01$) lower than that in cycling and running (Fig. 3A). Gender difference in cycling time was significantly ($P < 0.05$) lower compared with that in running. There was no significant age group × locomotion mode interaction for gender difference in estimated power output ($F = 0.94$, $P = 0.52$). Independent of age, gender differences in estimated power output differed between the locomotion modes ($F = 20.88$, $P < 0.001$). Gender difference in cycling power output was significantly ($P < 0.01$) greater than that in swimming and in running (Fig. 3B). Gender difference in swimming power output was significantly ($P < 0.01$) lower compared with that in running.

DISCUSSION

The main findings of the present study were as follows: first, gender differences in Ironman triathlon total performance time were stable until age 55 yr after which they significantly increased, and second, gender difference in performance time (swim < cycle < run) and estimated power output (swim < run < cycle) differed between the disciplines (i.e., mode of locomotion) of triathlon.

Although it lacked several physiological parameters, such as aerobic capacity, body weight, lean body mass, and training volume, this study offers valuable data. Elderly triathletes are able to maintain a high degree of physiological plasticity late into life and represent a fascinating model of exceptionally successful aging (31). The approach that consists of examining the changes in endurance performance with age in highly trained and competitive athletes represents an effective experimental model because changes observed with advancing age are thought to reflect mainly the results of primary (physiological) aging (30). The nature of the event (a world championship) meant that athletes likely performed to their maximal capacity, from both a mental and a physical perspective.

Gender difference in total performance time increases with age. The results suggested that the best age for the fastest Ironman total performance time is between 25 and 39 yr for both men and women. This was also true for cycling and running performance, where men and women within the 25–39 yr age range were faster compared with younger and older age groups. In contrast, the swimming performance times for both men and women remained quite similar between a larger range of years, i.e., between 18 and 44 yr. It has been suggested that the age-related decrease in maximal oxygen uptake seems to be the clearest and most consistent contributor to the decline in endurance performance with advancing age (31). Reductions in lactate threshold may also contribute, whereas submaximal exercise economy seems preserved with aging in endurance athletes (31). Our results showed that gender difference in total event performance time increased significantly with advancing age from 55 yr. Men triathletes at the age of 60 yr were, on average, 27% slower than the 30- to 40-yr-old triathletes, whereas the difference reached 38% for women. The exact reasons for these sex-related differences are not clear but could be due to a greater decline of one or more physiological determinants of endurance performance for women compared with men (e.g., maximal oxygen uptake, lactate threshold, and exercise economy). Even if one previous study (8) suggested that the relative rates of decline in maximal oxygen consumption with age are similar between men and women, age-related changes in the physiological determinants of endurance and ultraendurance performances between men and women have not received considerable attention.

However, interpretation of such cross-sectional comparisons of triathlon performance times across ages and sexes must be made carefully. It is possible that nonphysiological factors would have contributed to these observations. For example, the widening of gender difference with advancing age could be due at least in part to the fewer number of women triathletes in the older age groups. The percent of women participating at the Hawaii Ironman triathlon during the studied period corresponded, on average, to 27%, but "finisher" women in the age group 60–64 yr were usually less than 20%. This participation difference will no doubt diminish during the next couple of decades (because the percentage of women participating in the Hawaii Ironman triathlon was only 10%–15% in the 1990s; http://ironman.com/events/ironman). As a result, triathlon performances of the oldest women will probably improve more rapidly than those of the oldest men because the new generation of well-trained young women athletes moves into the older age group competition.

It is well established that the reduction in training volume and intensity may contribute to the larger declines in endurance performance of the elderly athletes (5,21). Some studies of older endurance athletes have indicated that the training volume of master athletes often is up to 50% lower compared with their younger peers (5,21). Differences in years of training, training volume, and intensity between elderly men and women triathletes performing in the Ironman triathlon may exist, but further work is required to clarify this. It would also require long-term follow-up of training diaries for all participants.

Gender difference differs between locomotion modes. For the 3.8-km swim, the magnitude of gender difference in the 18–64 yr age range was ∼12% in performance time and ∼28% in estimated power output. These values are in agreement with previous studies that examined long-distance swimming performance (14). Tanaka and Seals (29) examined gender differences in swimming performance time for distances from 50 to 1500 m and found that gender difference became smaller as swim distance increased ranging from ∼19% for the 50-m freestyle event to ∼11% for the 1500-m freestyle event. Because swimming is the first discipline of triathlon, and therefore, triathletes perform it in a relatively nonfatigued state, in the future, it would be interesting to compare gender difference

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in swimming performance during an Ironman distance triathlon with gender difference during a long-distance swim race. Independent of age, gender difference in performance time was smaller for swimming compared with that for cycling and running. One explanation for these differences between locomotion modes is the higher economy and mechanical efficiency of swimming in women compared with those in men. In contrast to running where the oxygen cost seems to be similar between women and men (e.g., Pate et al. [18]), the energy cost of freestyle swimming has been shown to be significantly higher (i.e., lower economy) in men (19). The higher mechanical efficiency of women has been attributed to their smaller body size (resulting in smaller body drag), smaller body density (greater fat percentage), and shorter lower limbs, resulting in a more horizontal and streamlined position and, therefore, a smaller underwater torque (12,19).

For cycling, the gender difference in the 18–64 yr age range was ~15% for performance time and ~39% for estimated power output. Compared with elite triathletes (14), these values are slightly greater for performance time (~13% in Lepers [14]) but are in a similar range for estimated power output (~38% in Lepers [14]). However, gender difference in power output in the present study might be underestimated because total elevation (~1400 m positive elevation over 180 km) is not accounted for in the cycling power model. There is a paucity of data in the literature concerning gender difference in cycling performance. In track cycling, where women are weaker than men in terms of power–weight ratios, the performance gap between men and women seemed constant (~11%) and independent of the race distance from 200 to 1000 m (23). Official time trial road cycling championships generally take place on distances much shorter than 180 km, and distances are greater for men than for women. Greater muscle mass and aerobic capacity in men, even expressed relative to the lean body mass (e.g., Levis et al. [15]), may represent an advantage during long-distance cycling, especially on a relative flat course such as Ironman cycling, where cycling approximates a non–weight-bearing sport. Indeed, it has been shown that absolute power output (which is greater for men than for women) is associated with successful cycling endurance performance because the primary force inhibiting forward motion on a flat course is air resistance (17).

In running, gender difference in the 18–64 yr age range was equal to ~18% in performance time and ~33% in estimated power output. The gender difference in performance time is greater than the difference found between elite men and women triathletes at the same Ironman triathlon (13% in Lepers [14]) but is similar to the values observed by Tanaka and Seals (29) for a 10-km run in masters athletes. It may be problematic to compare gender difference in an Ironman triathlon marathon with running performance during a marathon alone. However, Lepers (14) showed that, for the top 10 finishers, the gender difference in running at the Hawaii Ironman marathon was similar to running at the New York marathon (13%), suggesting that the swim and cycle portions of the triathlon do not exacerbate the gender difference in running. However, it could also be interesting in the future to compare for the same athletes the personal best time in a marathon alone and the best performance time in the Ironman triathlon marathon to examine whether fatigue differs between genders during a marathon of an Ironman triathlon. Previous studies suggested that the gender difference in running could diminish as distance increases past the marathon (e.g., Bam et al. [1]). Possible physiological advantages for women over men in long-distance running include greater fat utilization (and thus better CHO conservation) (32), higher proportions of maximal oxygen uptake (26), or greater muscle fatigue resistance (9). However, recent analysis of ultramarathon running performance suggested that gender difference remained stable for distances ranging from 50 to 161 km (6), with the fastest women running about 14%–20% slower than the fastest men (4,7). Morphological (body fatness) and physiological differences between sexes such as greater maximal oxygen uptake and oxygen-carrying capacities (hemoglobin concentration) may partly explain the gender difference in distance running performance (15). In contrast, running economy and lactate threshold do not seem to differ between men and women (e.g., Speechly et al. [26]).

Gender difference in actual performance time was greater for running (~18%) compared with that for swimming (~12%) and cycling (~15%); however, in contrast, gender difference in estimated power output was greater for cycling (~39%) compared with that for swimming (~28%) and running (~33%). The calculation of power in swimming and cycling is accurate only if the triathletes do not draft (i.e., swim or cycle behind another athlete). However, drafting during swimming was not controlled, and therefore, it might have influenced the assumed drag coefficient, thus invalidating the estimation of power output in swimming. At the Hawaii Ironman, triathletes are not allowed to draft in cycling (drafting is consistently checked by marshals), suggesting that the estimated power output in cycling is not affected by this confounding variable. Power output in swimming and cycling is related to an exponential expression of velocity, although it is directly related to velocity for running. A difference of 15% between men and women in cycling performance time (or velocity), therefore, does not correspond to a difference of 15% in physiological capacity because power output in cycling depends on the third power of velocity. Because power output is proportional to oxygen uptake, the magnitude of gender difference in power output provides a more correct representation of the underlying gender difference in physiological capacity (24).

CONCLUSIONS

The present study shows that the relative difference in performance time between women and men for an ultraendurance event such as the Ironman triathlon is stable until 55 yr and then it increases. The reasons for this increase are

not clear, and further studies examining, in particular, the changes in the training characteristics (volume and intensity) in elderly triathletes are required to better understand the age-related changes in Ironman triathlon performances. This study, conducted on amateur triathletes, also confirms previous findings obtained on elite triathletes, showing that gender difference differs between the locomotion modes (14), i.e., gender difference for swimming performance being smaller compared with running and cycling. However, the magnitude of gender difference for swimming, cycling, and running varies when performance time or estimated power output is considered. Further investigations are required to analyze the gender differences in performance time for ultraendurance events of different modes of locomotion such as open-water ultraswim, ultracycling, and running events (e.g., Knechtle and Kohler [11]) to see if gender differences change with length and nature of the endurance events.

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