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Influence of race distance and biological sex on age-related declines in triathlon performance. Part A

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Abstract

This study examined the effect of biological sex and race distance on the age-related declines in swimming, cycling, running and overall performances of the sprint, Olympic, Half-Ironman and Ironman triathlons. Individual discipline and overall performance time of the top 20% non-elite males (n=468) and females (n=146) were compared by categorizing into four 10-year age-groups (20-29, 30-39, 40-49, 50+ years) and normalising to the mean performance time of the fastest age-group for each race. An earlier, larger and faster rate of decline (p=0.01) in performance with ageing was observed in females (≥30 years, 9.3%, 3.0% per decade respectively) and males (≥40 years, 5.9%, 2.2% per decade, respectively) for the longer events (half-Ironman and Ironman) compared with the shorter distances (sprint and Olympic, ≥50 years for both sexes). A greater magnitude of decline was observed in swimming for both sexes, especially in the longer events, when compared with cycling and running (12.8%, 5.6%, 9.3% for females, 9.4%, 3.7%, 7.3% for males, in the swim, cycle and run disciplines, respectively). These results indicate that both race distance and biological sex influence the age-related decline in triathlon performance and could aid athletes in optimising training programs to attenuate the age-related declines in performance across different disciplines and distances. Specifically, older athletes may benefit from greater emphasis on swim training and factors that may influence performance during longer distance triathlons.

Keywords: sprint triathlon; Olympic triathlon; half-ironman triathlon; ironman triathlon; gender

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Introduction

In physically active individuals, endurance performance is maintained until approximately 35 years of age, followed by modest decreases (5-10% per decade) up to 50-60 years, and progressively steeper declines thereafter (Tanaka and Seals 2003, 2008). Associated with these changes, the age-related decline in endurance performance appears to differ depending upon the duration of activity (Joyner 1993). Indeed, Lepers et al. (2010) observed a greater age-related decline in top 10 male cycle and run performance for the Ironman triathlon (~9 h), compared with the Olympic distance triathlon (~2 h), which may reflect greater physiological and mechanical demands associated with ultra-endurance events (Lepers et al. 2010).

Irrespective of exercise duration, sociological (non-biological) and physiological differences between sexes typically results in endurance performance being 10-15% slower in females compared with males (Lepers and Maffiuletti 2011). Furthermore, this difference between sexes has been shown to widen with age (Tanaka and Seals 1997), possibly due to a greater rate of muscle mass loss in females, especially beyond menopause (Phillips et al. 1993). To date, majority of studies examining the interaction of age and/or biological sex on endurance performance have focused on sports such as swimming (Donato et al. 2003; Stefani 2006; Zamparo 2006), cycling (Dore et al. 2005; Schumacher et al. 2001), running (Tanaka and Seals 2003), rowing (Seiler et al. 1998) and duathlon (Rust et al. 2013). Tanaka and Seals (1997) examined the sex and age-related decline during the US Masters Swimming Championships and observed a greater decline in females compared with males over both short- (50 m) and long- (1500 m) duration events. Conversely, Schumacher et al. (2001) found no interaction in sex differences during world track cycling championships for 200 m, 1000 m, individual and team pursuit races. As such, it appears that the influence of sex on the age-related declines in endurance performance may differ depending on exercise duration and interaction of different modes of locomotion.

To date, few studies have examined the interaction between sex and age during multi-sport events such as triathlon (Etter et al. 2013; Knechtle et al. 2012; Lepers and Maffiuletti 2011;Stevenson et al. 2013). Triathlon is a unique sport that allows for comparison of the age and sex effects between sequential disciplines (i.e. swim, cycle and run) and over various race distances/durations (~1 to 17 h, for a review, see Lepers et al. 2013). Research examining the Ironman triathlon has shown similar declines in performance between sexes until 55 years, after which females declined at a significantly faster rate (Lepers and Maffiuletti 2011). Furthermore, sex differences within this study were found to be greatest in the run, followed by the cycle and swim disciplines (18.2%, 15.4% and 12.1%, respectively). Conversely, in a separate study, an earlier divergence in sex difference was observed in the Olympic distance (after 35 y), with a slight difference in the gap between males and females over the various disciplines (i.e. run- 17.1%; cycle- 13.4%; swim - 15.2%, Etter et al. 2013). Collectively, these studies provide evidence to suggest that the age-related declines in triathlon performance between males and females may depend on both discipline and race distance.

It is also important to note that the sex and age differences in performance could be affected by the drafting nature of triathlons. Indeed, the conservation of energy through drafting could influence race tactics, especially within the cycle discipline, and may significantly impact race outcome (Hausswirth and Brisswalter 2008). Consequently, careful consideration should be made when comparing drafting and non-drafting races (Stevenson et al. 2013). Since the cycle discipline of non-drafting races is performed more similarly to an individual time-trial (Abbiss et al. 2006), such races may provide an ideal model to examine the age- and sex-related changes in triathlon performance.

To date, however, we are unaware of any studies that have extensively examined the effect of biological sex and race distance on overall and discipline-specific performance over the four standard triathlon distances during non-drafting races (sprint: ~1 h, Olympic: ~2 h, half-Ironman: ~5 h and Ironman: ~8-17 h). Elucidating the effect of these factors on triathlon performance could help to identify training strategies necessary to improve performance in ageing male and female athletes. Hence, the purpose of this study was to examine the influence of biological sex and race distance on the age-related declines in swimming, cycling, running and overall performances during the sprint, Olympic, half-Ironman and Ironman distance triathlons.

Materials and methods

Completion times for the swim, bike and run and overall triathlon of non-drafting top age group male and female participants (≥18 y) in four standard distance triathlons were examined. The distances included a sprint (n=245 for males and 95 for females), an Olympic (n=265 and 80), a half-Ironman (n=905 and 335), and an Ironman (n=925 and 220) triathlon as described below. In order to examine differences in performance amongst the best performing athletes, only the top 20% of non-drafting overall finishers in each age group of both sexes were analysed (as opposed to a specific number of athletes to minimise the disparities caused by dissimilar participation rates between age groups). Prior to data collection, ethical clearance was obtained from the Edith Cowan University human research ethics committee, in accordance with the Australian National Statement on Ethical Conduct in Human Research, and complied with the ethical standards of JSC (Harriss and Atkinson 2009).

To ascertain performance times, official race transponders were worn by participants throughout each race, which transmitted a time signal through a radio-frequency timing system at specific locations determined by the race organisers. The locations included the end of the swim, bike and run leg in each race (described below). The swim, cycle, run and overall race results were downloaded from official competition websites following each event. Racing commenced at 0720 hrs (± 68 min) in all conditions with an open water swim.

The sprint triathlon consisted of a 750 m swim, 20km cycle and a 5 km run. The cycle leg involved four laps of 5 km circuit (highest elevation of 6.68 m) while the run was an out and back course (highest elevation of 11.1 m). Mean completion race time was 82 ± 10 min (results from http://www.bluechipresults.com.au/default.aspx?CId=11&RId=2068). The 1.5 km swim, 40 km cycle, 10 km run Olympic distance triathlon was completed in a time of 166 ± 19 min (http://www.bluechipresults.com.au/default.aspx?CId=11&RId=2064). The bike leg consisted of four laps of 10 km with a highest elevation of 6.59 m, and the run was three laps of 3.33 km with an elevation of 2.26 m. The mean completion time for the half-Ironman event (1.9 km swim, 90 km cycle, 21.1 km run) was 333 ± 43 min (http://www.bluechipresults.com.au/Results.aspx?CId=11&RId=6032&EId=1). Following the swim, participants performed a two lap (45.05 km each) bike course with a highest elevation of 21.3 m, followed by a three lap (7.03 km each, elevation of 1.5 m) run. The Ironman event (3.8 km swim, 180 km cycle, 42.2 km run) was completed in 708 ± 97 min (http://www.ironman.com/triathlon/events/asiapac/ironman/western-australia/results.aspx?rd= 20111204). It was held in the same vicinity of the Busselton half-Ironman and includes a one loop swim, three loop bike ride (elevation change of 12.3 m) and 4 loop run (elevation change of 1.5 m).

Based on the official timing system, the elapsed time for each discipline and entire course was determined for each of the participants in all distances (Table 1). To allow detection of meaningful differences, athletes were separated between sex (male and female) and into four 10 y age-groups (20-29, 30-39, 40-49, 50+ y inclusive). Since the minimum age of athletes in the sprint and Olympic distances was 20 y, all 18-19 y old participants in the half-Ironman and Ironman events in this study were included in the 20-29 y age group for analysis.

standard deviation of the performance ratio for each discipline was compared to examine the variability in performance between disciplines.

Table 1. Overall, swimming, cycling and running performance times for the top 20% of female (F) and male (M) in each age group at the sprint, Olympic, half-Ironman and Ironman distance triathlons. Values are expressed in minutes (mean±SD).

	Sprint (min)				Olympic (min)			
Age Category	**Overall**	**Swim**	**Cycle**	**Run**	**Overall**	**Swim**	**Cycle**	**Run**
F20-29	76.0 ± 2.9	13.3 ± 1.5	41.0 ± 1.6	21.8 ± 1.4	154.4 ± 3.5	25.0 ± 1.5	80.8 ± 3.3	48.5 ± 2.4
F30-39	77.9 ± 3.5	14.6 ± 1.4	41.5 ± 2.4	21.7 ± 1.5	157.2 ± 6.4	29.3 ± 2.9	78.2 ± 2.3	49.7 ± 4.3
F40-49	74.3 ± 1.5	13.9 ± 1.3	39.4 ± 1.0	21.0 ± 1.1	153.0 ± 2.3	28.3 ± 2.8	77.6 ± 0.7	47.0 ± 2.7
M20-29	67.9 ± 2.0	12.5 ± 1.4	36.2 ± 1.7	19.2 ± 1.3	142.2 ± 4.3	26.8 ± 2.2	72.0 ± 2.6	43.4 ± 3.2
M30-39	68.7 ± 3.0	12.9 ± 1.3	35.8 ± 1.6	20.0 ± 1.5	144.9 ± 5.6	29.1 ± 3.3	71.4 ± 2.4	44.4 ± 3.5
M40-49	68.8 ± 1.6	13.1 ± 0.9	35.8 ± 1.3	20.0 ± 0.8	147.0 ± 4.2	28.3 ± 1.8	72.1 ± 3.0	46.6 ± 3.1
M50+	71.3 ± 1.3	13.5 ± 1.4	37.1 ± 1.5	20.6 ± 1.0	146.5 ± 4.1	28.8 ± 2.9	72.6 ± 2.9	45.0 ± 3.3
	Half-Ironman (min)				**Ironman (min)**			
Age Category	**Overall**	**Swim**	**Cycle**	**Run**	**Overall**	**Swim**	**Cycle**	**Run**
F18-29	296.2 ± 8.8	31.2 ± 2.9	160.4 ± 6.4	100.5 ± 5.8	621.9 ± 14.2	62.5 ± 4.0	329.8 ± 10.1	222.5 ± 9.6
F30-39	309.6 ± 13.5	33.5 ± 3.5	164.9 ± 6.6	106.5 ± 8.0	644.9 ± 22.9	66.5 ± 6.4	335.1 ± 14.3	236.2 ± 14.0
F40-49	320.4 ± 8.1	36.0 ± 1.9	167.6 ± 4.6	111.9 ± 6.8	646.2 ± 32.8	65.1 ± 3.4	329.1 ± 12.6	245.2 ± 24.5
F50+	317.7 ± 17.3	34.8 ± 3.5	165.1 ± 5.2	112.8 ± 11.3	704.9 ± 24.7	73.8 ± 7.6	359.8 ± 16.0	261.7 ± 18.0
M20-29	274.0 ± 11.6	29.6 ± 3.3	148.0 ± 7.3	92.8 ± 9.3	577.0 ± 20.7	58.0 ± 5.4	304.5 ± 13.4	209.0 ± 15.3
M30-39	275.3 ± 7.9	31.2 ± 2.6	146.9 ± 4.6	93.3 ± 5.4	577.3 ± 22.7	58.6 ± 5.0	302.6 ± 11.1	210.6 ± 14.5
M40-49	284.8 ± 11.2	31.6 ± 2.8	150.1 ± 6.9	98.6 ± 7.5	615.4 ± 32.7	62.4 ± 7.3	315.2 ± 18.3	230.0 ± 19.3
M50+	289.9 ± 10.4	32.1 ± 3.0	153.4 ± 6.8	99.9 ± 5.9	615.7 ± 26.7	65.2 ± 5.3	317.0 ± 11.9	225.7 ± 14.8

To allow meaningful comparisons between groups (i.e. biological sex, age group, race distance and disciplines) and to reduce the influence of environmental, topographical, distance factors and performance outliers, a ratio of the age-related decline in performance was calculated. The performance ratio was defined as the mean swim, cycle, run and overall performance time of each individual normalised to the mean performance time of the fastest age group in the respective sex, distance and race:

Performance ratio = *Mean performance time of discipline by individual / Mean performance time of fastest age group for that discipline in the specific race*

The magnitude of decline (from 20 to 50+ y) was determined for the overall, swim, cycle and run performance ratio collectively over the four distances, and also for the shorter (sprint and Olympic) and longer (half-Ironman and Ironman) distances separately. As analysis showed no significant difference in performance ratio between the Sprint and Olympic, or the half-Ironman and Ironman distances (Figure 1), the two shorter and two longer distances were combined for subsequent analysis to allow a distinct comparison of the distance effect on performance. The rate of decline in performance was calculated for each discipline and each race distance based on the linear relationship between age and the performance ratio of each decade. A linear relationship was determined for the shorter and longer distances separately. The percentage of time spent in each discipline relative to the overall race completion time (i.e. relative contribution time) was determined for each event. The All statistical tests were conducted using PASW Statistics (version 18.0, Chicago, Illinois). The magnitude of decline and performance ratio for the overall, swim, cycle and run of each age group were compared between distance, age groups and sex using a three-way analysis of variance (ANOVA). Comparisons between dependant variables were analysed using a two-way ANOVA followed by Gabriel's post-hoc. The relative time contribution of each discipline as a percentage of overall performance time (irrespective of sex) was compared between race distances using a one-way ANOVA. The standard deviation of the performance ratio of each discipline was compared using a one-way ANOVA. Games-Howell post-hoc test was used to determine where the differences lie. Significance was set at $p<0.05$. All results are expressed as mean±SD.

Results

The swimming, cycling, running and overall performance ratio of the top 20% male and females are presented in Figure 1. Collectively over the four distances, an earlier and greater magnitude of age-related decline (from 20 to 50+ y, $p=0.014$) was observed in overall performance of females (≥30 y, 8.4%) when compared with males (≥40 y, 5.6%). In the shorter distances, overall performance was maintained up to 49 y in both sexes, and the magnitude and rate of decline in overall performance were not significantly different between sexes (3.8%, 1.2% per decade for males, -1.6%, -0.80% per decade for females, respectively). In the longer distances, an earlier, larger and faster rate of decline ($p=0.01$) was observed in the females (≥30 years, 9.3%, 3.0% per decade, respectively), compared with males (≥40 y, 5.9%, 2.2% per decade, respectively).

Discipline-specific analysis revealed that, in the shorter distances, an initial age-related decline in swim performance was observed after 29 y for both males and females, and the magnitude of decline was similar between males (7.3%, p=0.011) and females (7.9%, p=0.01, Figure 1). No significant difference in decline during the cycling and running performance was observed between males (1.6%, 5.4% respectively) and females (-3.8%, -3.3% respectively) in the shorter distances. During the longer events, female performance decreased to a greater extent (12.8%, 5.6% and 9.3%, p=0.01) as compared with males (9.4%, 3.7% and 7.3%, p=0.01) across the swim, cycle and run discipline respectively. During the run discipline in the Ironman, the initial age-related decline in male performance was observed after 39 y (p=0.002), compared with 49 y in females (p=0.012).

Relative time contribution of the swim, cycle and run discipline towards overall performance time was not significantly different between sexes. The relative contribution of the swim discipline during the shorter distances, regardless of sex, was higher (18.7%), compared with the longer distances (10.6%, p=0.01). The relative time contribution for the run discipline significantly increased with each increasing race distance (28.6, 31.1, 34.5, 36.8%, p=0.01, for sprint, Olympic, half-Ironman and Ironman distance, respectively; Figure 2).

The standard deviation (indicating within group variability) of the normalized performance ratio in both males and females for each discipline increased significantly in the order of cycle < run < swim (Figure 2, p=0.038), however, no differences were observed between sexes for all disciplines.

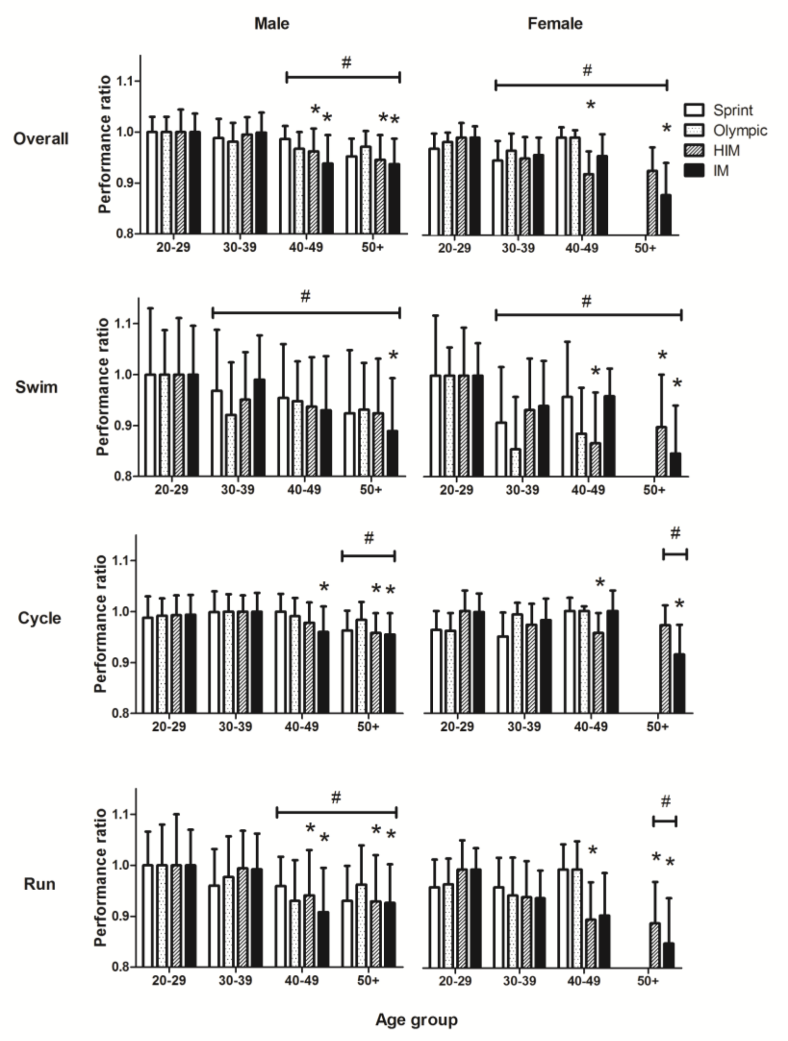

Figure 1. Overall, swim, cycle and run performance for the top 20% male and female in each age group (20-29, 30-39, 40-49, 50+) for the sprint, Olympic, half-Ironman (HIM) and Ironman (IM) distance triathlon. #: significantly slower than younger age group. *: significantly slower than fastest age group in the respective distances.

Discussion

The present study examined the effect of biological sex and race distance on the age-related decline in swimming, cycling, running and overall performances during a sprint, Olympic, half-Ironman and Ironman distance triathlon in top 20% non-elite finishers. To the authors' knowledge, this is the first study to compare the effect of biological sex and age on age-related declines in triathlon performance across the four standard triathlon distances. The main findings are that: i) collectively, triathlon performance decreases with increasing age, however to a greater extent and faster rate in females during longer distance racing, ii) performance decline in all disciplines occurs at an earlier age in the longer (half-Ironman and Ironman) races as compared with the shorter (sprint and Olympic) distances in both sexes, and iii) swim performance decreases at an earlier age compared with cycle and run regardless of distance.

In this study, the decrease in overall triathlon performance with age was observed beyond 39 years in males and 29 years in females, with a marked decline in performance beyond 50 years for both sexes. Such age-related declines in performance have been attributed to a reduction in maximal aerobic capacity (Lepers et al. 2013; Tanaka and Seals 2003), loss in muscle strength and muscle mass, reduced satellite cell content that is essential for the repair and hypertrophy of skeletal muscle (Verdijk et al. 2007), declines in gluconeogenic and glyconeogenic capabilities (Podolin et al. 1994), and a reduced training “stimulus” with advancing age (Lepers et al. 2010; Rittweger et al. 2009). Furthermore, the greater age-related decline in overall triathlon performance observed in the females, compared with males, is associated with greater post-menopausal strength loss (Joyner 1993) and higher susceptibility to deteriorations in maximal aerobic capacity (Tanaka and Seals 1997, 2003). Indeed, the magnitude of decline in overall performance from age 20 to 50+ years across all distances was 8.4% for females, compared with 5.6% for males.

Non-biological factors such as participation rates could partly explain sex-related performance differences (Lepers et al. 2013). The attrition in participation numbers increases with age, especially in the female population (Lepers et al. 2013; Lepers and Maffiuletti 2011). As a result, the lesser 146 females, compared with 468 male participants, could account for a higher variability in female performance, as indicated by a larger but insignificant increase in the standard deviation of performance ratios in females across all disciplines and overall performance. In an attempt to partly account for this, we examined only the top 20% of all male and female athletes in each age group rather than a predetermined sample size (e.g. the top 10 athletes). Importantly, it should be noted that the differences between male and female performance were not consistent across different race distances and triathlon disciplines.

The effect of distance on the age-related decline in performance was not apparent between the two shorter distances for overall, swim, cycle and run disciplines from 20 to 50+ years, with the fastest mean time for females in both distances observed from 40-49 years. This novel finding is suggestive of a protective effect against loss in functional muscle strength produced by the training load of the top 20% athletes, which could assist in maintaining exercise performance in the shorter events (Hawkins et al. 2003). However, an earlier age-related decline was observed in both males (≥40 years) and females (≥30 years) during the longer half-Ironman and Ironman. Indeed, there is evidence to suggest that self-selected exercise intensity progressively decreases during endurance events lasting more than 4 h, attributed to the psychological and metabolic factors of neuromuscular fatigue (Abbiss and Laursen 2008). In addition, the importance of optimising pre-exercise metabolic reserves and substrate utilisation during the event through manipulations of diet becomes increasingly crucial with longer race duration (Laursen and Rhodes 2001; Tucker and Noakes 2009). In older athletes, the reduction in muscle cross-sectional area which reduces overall muscle oxidative enzyme activity and muscle capillarisation (Rogers and Evans 1993), coupled with a lower reliance on fat metabolism during moderate intensity exercise and lower resting muscle glycogen stores (Mittendorfer and Klein 2001), could help to explain the larger decrease in performance.

When examining performance within each discipline, the magnitude of decline for both sexes was greatest during the swim, followed by the run and then the cycle discipline across all distances (Figure 1). This pattern of decline among the different disciplines is similar to previous research on Olympic (Etter et al. 2013; Lepers et al. 2010) and Ironman (Lepers and Maffiuletti 2011; Lepers et al. 2010) distance triathlons. This observation could reflect the different physiological demands of the various disciplines. For instance, swimming requires high physical capacity and strength (Geladas et al. 2004), which is impaired with age due to sarcopenia. Similarly, the more rapid atrophy of fast twitch fibres, compared with loss of slow twitch fibres with age (Faulkner et al. 2008), could be more debilitating to run than cycle performance due to the stretch shortening cycle in running. One could perceive more benefit from an emphasis on cycling, due to the relatively lower percentage of race time spent during swimming (~15%) and running (~33%), compared with cycling across distances (~52%, Figure 2), as indicated, at least in part, by the smallest age-related decline in cycling among the 3 disciplines across distances and sex (Figure 1).

Interestingly, the initial decline in run performance for males was observed after 39 years, compared with 49 years in females. The later decline in females may be due to enhanced fat metabolism during exercise, thereby conserving carbohydrate stores (Knechtle et al. 2004). Indeed, since running is the last discipline during a triathlon, conservation of carbohydrate stores would likely be more advantageous to run performance. Furthermore, post hoc analysis revealed that this sex bias in running performance was observed in the Ironman event, which is highly influenced by carbohydrate availability (Abbiss and Laursen 2005). These results are in accordance with recent observations of elite females reducing the gap between sexes for the marathon run of the Ironman distance (Lepers et al. 2013). Further research is needed to examine the physiological factors that may be associated with the sex, distance and discipline specific biases observed in the age-related decline in performance.

Limitations

The main limitation of this study was a lack of physiological data pertaining to participants (i.e. thresholds, aerobic capacity and anthropometrical data) to further elucidate the relationship between sex, age and performance in various triathlon distances. However, this is the first study to examine the age-related decline endurance exercise during various triathlon distances in both sexes, and offers novel data which could influence methods of training in triathlon. Furthermore, the large number of participants in this study increases the reliability and applicability of these results to the four standard triathlon distances.

Conclusions

Triathlon performance in the sprint and Olympic distance is maintained up to 50+ years for both sexes, but decreases earlier during longer distance racing due to higher metabolic demands of the half-Ironman and Ironman events. This decrease is more apparent in females, and could be due to a greater decrease in maximal aerobic capacity and loss in muscle strength. A greater magnitude of decline was observed in the swim as compared with and cycle and run discipline across distances. These observations can have implications for athletes and coaches in developing training programs and race strategies to assist in attenuating the age-related decline in triathlon performance. Future studies providing in-depth race analysis and the physiological responses of athletes during various distances could further our understanding of the influence of sex and age on triathlon.

Practical applications

The higher and more rapid decline in female triathlon performance with age should be taken into consideration during training periodisation. More emphasis could be placed on the swimming discipline with ageing across the sprint, Olympic, half-Ironman and Ironman distances. Shorter distance triathlons (sprint and Olympic) may be more favourable for ageing athletes; ageing athletes need to consider the detrimental effect of distance during the half- and full Ironman events.

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Conflict of interest

No conflict of interest was declared for all authors.

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