

# Age-Related Changes in Triathlon Performances

## Authors

R. Lepers<sup>1</sup>, F. Sultana<sup>2</sup>, T. Bernard<sup>2</sup>, C. Hausswirth<sup>3</sup>, J. Brisswalter<sup>4</sup>

## Affiliations

<sup>1</sup>UFR STAPS – Université de Bourgogne, INSERM – U887 Motricité – Plasticité, DIJON, France

<sup>2</sup>University of Toulon-Var, Spor Ergonomic and performance, La Garde, France

<sup>3</sup>INSEP, Biomechanics and Physiology, Paris, France

<sup>4</sup>Université de Nice Sophia Antipolis, LAHMES, Nice, France

## Key words

- master athletes
- endurance
- ageing

## Abstract

The aim of this study was two-fold: i) to analyse age-related declines in swimming, cycling, and running performances for Olympic and Ironman triathlons, and ii) to compare age-related changes in these three disciplines between the Olympic and Ironman triathlons. Swimming, cycling, running and total time performances of the top 10 males between 20 and 70 years of age (in 5 years intervals) were analysed for two consecutive world championships (2006 and 2007) for Olympic and Ironman distances. There was a lesser age-related decline in cycling performance ( $p < 0.01$ ) compared with running and swimming after 55 years of age for Olympic distance

and after 50 years of age for Ironman distance. With advancing age, the performance decline was less pronounced ( $p < 0.01$ ) for Olympic than for Ironman triathlon in cycling ( $> 55$  years) and running ( $> 50$  years), respectively. In contrast, an age-related decline in swimming performance seemed independent of triathlon distance. The age-related decline in triathlon performance is specific to the discipline, with cycling showing less declines in performance with age than swimming and running. The magnitude of the declines in cycling and running performance at Ironman distance is greater than at Olympic distance, suggesting that task duration exerts an important influence on the magnitude of the age-associated changes in triathlon performance.

## Introduction

The age-related decline in endurance exercise performance is well documented. In general, peak endurance performance is maintained until ~35 years of age, followed by modest decreases until 50–60 years of age, and a progressively steeper decline thereafter [26]. However, most studies examining masters athletes have focused on running for different distances up to the marathon [28]. Fewer studies, however, have examined the age-related decline in performance of other modes of locomotion such as swimming and cycling. Donato et al. [8] for example, suggested that the rates of decline in swimming performance with age were greater in a long-duration (1500 m) than in short-duration (50 m) events, because of a relatively smaller loss of anaerobic muscular power with age compared with cardiovascular endurance. Similarly, few studies have examined the age-related decline in cycling. Balmer et al. [1,2] for example, examined the age-related decline in cycling performance for an indoor 16 km time-trial. Cycling may show differ-

ences in the age-related decline compared to running because of the contraction types involved. Cycling is a non-weight bearing activity that employs predominantly concentric muscle activation compared with the stretch-shortening activity and eccentric activations during running. As older adults show different rates of decline during fatiguing contractions that involve eccentric as opposed to concentric activations, this may explain differences in the rate of decline in cycling versus running [3].

Triathlon, involving successive swimming, cycling and running sessions, represents an interesting model to examine the age-related changes in endurance performance in different locomotion modes. Official competition in triathlon varies from short distance named “Olympic triathlon” (1.5 km swim, 40 km cycling, and 10 km running) to long distance named also “Ironman triathlon” (3.8 km swim, 180 km cycling, and 42.2 km running) [4,14].

Bernard et al. [5] recently showed that for Olympic triathlon, performance times in the three disciplines declined with advancing age in a

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## Bibliography

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## Correspondence

### Dr. Romuald Lepers

UFR STAPS – Université de Bourgogne  
INSERM – U887 Motricité – Plasticité  
21078 BP 27877 DIJON  
France  
Tel.: +33 (0)3-80-39-67-60  
Fax: +33 (0)3-80-39-67-02  
romuald.lepers@u-bourgogne.fr

curvilinear manner although the pattern of decline was specific for each locomotion mode. Cycling for example, demonstrated the least age-associated decline compared to running and swimming. This observation suggests that physiological functional capacity and performance appears to be more resistant to biological aging in cycling than the two other disciplines. During a longer event, the age-related differences between cycling, running and swimming maybe even greater because the physiological and mechanical stresses that occur during Ironman triathlon are much greater compared to those encountered during the Olympic distance triathlon. For example, during an Ironman triathlon, energy expenditure ranges from 8500–11000 kcal [13]. The number of impact forces during the Ironman marathon running are also much greater compared with a 10 km run. Because of the different physiological demands between Olympic and Ironman distance triathlons, the age-related declines in performance may differ between both distances. Therefore, the purpose of this study was: 1) to determine if there was a reduced rate of decline in cycling performance with advancing age compared to running and swimming for the Ironman triathlon, as has been previously shown for Olympic triathlon, and 2) to compare age-related changes in swimming, cycling, and running performances between the Olympic and Ironman distance triathlons.

## Materials and Methods

Swimming, cycling, running and total time performances of the top 10 non-elite males of 11 age groups were analysed. The age groups distinguish the categories for each period of 5 years as follows with the corresponding associated code in brackets: 18–24 years (20), 25–29 years (25), 30–34 years (30), 35–39 years (35), 40–44 years (40), 45–49 years (45), 50–54 years (50), 55–59 years (55), 60–64 years (60), 65–69 years (65) and 70–74 years (70).

For the *Olympic triathlon*, the data set was obtained from the International Triathlon Union Web site: <http://www.triathlon.org>. Data were assessed for two consecutive world championships taking place in Lausanne (2006) and Hamburg (2007).

For the *Ironman triathlon*, the data set was obtained from World Triathlon Corporation Web site: <http://www.ironmanlive.com>.

The world Ironman triathlon championship takes place every year in Kailua-Kona, Hawaii since 1981 [14]. Data were assessed for two consecutive Hawaii Ironman races in 2006 and 2007.

The mean time performance of the top 10 of the best performing age group for each individual discipline was very similar between 2006 and 2007 for both Olympic and Ironman triathlons (see results), so we pooled two years of data. For the Olympic and Ironman triathlons, the performances of 20 triathletes per age group (i.e. the top 10 of each age group in 2006 and in 2007) were considered. For each year and both distances, the swimming, cycling, running and overall time performances of each triathlete finishing in the top 10 of each age group was normalized to the mean time performance of the top 10 of the best performing age group. Thus, the age-related declines in performance were expressed using a ratio calculated between the individual and the mean time performances of the best performing age group for each mode of locomotion and total time.

## Statistical analysis

Data are reported as means  $\pm$  SD with the text and displayed as means  $\pm$  SE in the figures. Two-way ANOVAs with repeated-measures on locomotion mode were used to compare performance ratio between modes of locomotion across ages for Olympic and Ironman triathlons. For each mode of locomotion and total time performance, two way ANOVAs (age  $\times$  distance) were used to compare performance ratios between Olympic versus Ironman triathlon across age. Post hoc analysis (Tukey) was used to test for differences within the ANOVAs when appropriate. A significance level of  $P < 0.05$  was used to identify statistical significance.

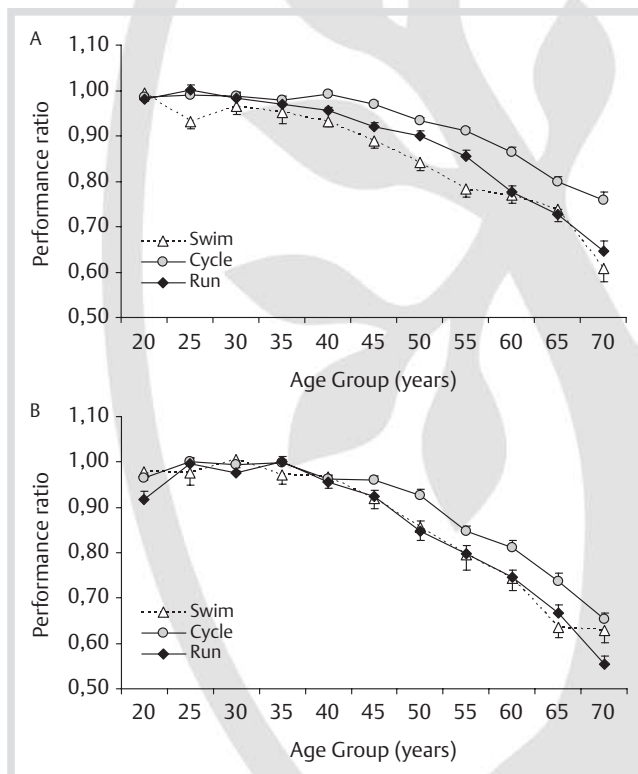
**Table 1** Swimming, cycling, running, and total performance times for the top 10 males in each age group at the world triathlon championships. For Olympic triathlon, data from Lausanne (2006) and Hamburg (2007) were averaged. For Ironman triathlon, data from Hawaii Ironman in 2006 and 2007 were averaged. Values are mean  $\pm$  SD.

	Age groups (years)										
	18–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74
<b>olympic triathlon</b>											
1.5 km swim (min:s)	20:20	21:45	21:02	21:24	21:44	22:50	24:07	25:58	26:25	27:44	34:00
	$\pm$ 1:19	$\pm$ 1:15	$\pm$ 1:11	$\pm$ 1:39	$\pm$ 0:51	$\pm$ 1:12	$\pm$ 1:29	$\pm$ 1:54	$\pm$ 2:09	$\pm$ 3:03	$\pm$ 5:14
40 km cycle (h:min:s)	1:02:13	1:01:54	1:01:57	1:02:31	1:01:43	1:03:07	1:05:33	1:07:18	1:10:53	1:16:40	1:21:12
	$\pm$ 2:03	$\pm$ 1:59	$\pm$ 1:33	$\pm$ 1:50	$\pm$ 2:24	$\pm$ 2:21	$\pm$ 2:34	$\pm$ 2:36	$\pm$ 3:46	$\pm$ 3:30	$\pm$ 7:11
10 km run (min:s)	35:56	35:11	35:48	36:20	36:50	38:16	39:08	41:13	45:24	48:34	55:13
	$\pm$ 1:44	$\pm$ 1:26	$\pm$ 1:29	$\pm$ 1:37	$\pm$ 1:02	$\pm$ 1:31	$\pm$ 1:50	$\pm$ 2:00	$\pm$ 2:42	$\pm$ 2:47	$\pm$ 7:29
total (h:min:s)	2:05:56	2:06:15	2:06:22	2:07:53	2:08:10	2:12:24	2:17:30	2:23:37	2:32:57	2:44:10	3:04:15
	$\pm$ 5:22	$\pm$ 4:21	$\pm$ 4:10	$\pm$ 3:30	$\pm$ 4:31	$\pm$ 5:30	$\pm$ 4:52	$\pm$ 4:39	$\pm$ 7:50	$\pm$ 6:56	$\pm$ 16:37
<b>ironman triathlon</b>											
3.8 km swim (h:min:s)	1:01:38	1:02:04	1:00:07	1:02:09	1:02:35	1:05:44	1:11:04	1:16:51	1:21:49	1:35:51	1:37:26
	$\pm$ 4:01	$\pm$ 5:22	$\pm$ 4:30	$\pm$ 4:05	$\pm$ 5:23	$\pm$ 5:00	$\pm$ 8:05	$\pm$ 10:35	$\pm$ 9:36	$\pm$ 10:46	$\pm$ 13:34
180 km cycle (h:min:s)	5:04:17	4:53:24	4:55:26	4:54:01	5:05:25	5:06:15	5:17:44	5:47:18	6:03:24	6:40:18	7:30:09
	$\pm$ 10:08	$\pm$ 7:32	$\pm$ 8:46	$\pm$ 6:04	$\pm$ 8:15	$\pm$ 11:11	$\pm$ 15:10	$\pm$ 16:37	$\pm$ 22:58	$\pm$ 32:02	$\pm$ 25:54
42 km run (h:min:s)	3:23:08	3:07:03	3:10:37	3:05:58	3:14:52	3:21:41	3:40:31	3:53:51	4:10:26	4:40:56	5:38:55
	$\pm$ 11:12	$\pm$ 6:43	$\pm$ 7:04	$\pm$ 6:06	$\pm$ 9:11	$\pm$ 9:13	$\pm$ 17:50	$\pm$ 15:38	$\pm$ 16:42	$\pm$ 23:51	$\pm$ 33:27
total (h:min:s)	9:35:26	9:08:22	9:11:57	9:07:53	9:29:23	9:40:27	10:16:40	11:07:21	11:46:38	13:09:27	15:02:17
	$\pm$ 11:41	$\pm$ 8:56	$\pm$ 7:36	$\pm$ 7:34	$\pm$ 10:04	$\pm$ 13:47	$\pm$ 21:33	$\pm$ 31:07	$\pm$ 28:47	$\pm$ 41:51	$\pm$ 56:58

## Results

The mean time performances of the top 10 of the best performing age group for each discipline were very similar between 2006 and 2007 for both Olympic and Ironman triathlons. For Olympic triathlon, time performance (expressed as h:min:s) was : 0:20:42±0:01:24, 1:02:51±0:01:30, 0:35:55±0:01:19 in 2006 and 0:19:59±0:00:58, 1:00:21±0:00:34, 0:34:27±0:01:12 in 2007, for 1.5km swimming, 40km cycling and 10km running, respectively. For Ironman triathlon, time performance (expressed as h:min:s) was: 1:00:58±0:04:44, 4:50:01±0:05:05, 3:04:54±0:05:50 in 2006 and 0:59:08±0:02:05, 4:56:47±0:07:52, 3:06:46±0:05:51 in 2007, for 3.8km swimming, 180km cycling and 42.2km running, respectively.

Swimming, cycling, running and total time performances for each age group for both Olympic and Ironman triathlons are presented in **Table 1**. The relative contribution of each part of the overall performance remains constant across the ages for both distances. For Olympic triathlon, the 1.5 km swimming, 40 km cycling, and 10 km running represent on average 17.2±0.6, 47.6±1.6, 28.8±0.6 % of the total time, respectively. For Ironman



**Fig. 1** Age-related declines in swimming, cycling and running performances for the Olympic (**Panel A**) and Ironman triathlons (**Panel B**), (mean ± SE). For Olympic triathlon, the performance ratio was significantly different ( $p < 0.01$ ) from the previous age group, from age group 40 for swimming, from age group 50 for running, and from age group 55 for cycling, respectively. Cycling performance ratio remained significantly ( $p < 0.01$ ) greater than swimming from age group 40 onwards, and from age group 45 cycling performance ratio remained significantly ( $p < 0.01$ ) greater than running. For Ironman triathlon, the performance ratio was significantly different ( $p < 0.01$ ) from the previous age group, from age group 45 for swimming and running, and from age group 50 for cycling. Cycling performance ratio remained significantly ( $p < 0.01$ ) greater than swimming from age group 45 onwards (except for age group 70), and from age group 50 cycling performance ratio remained significantly ( $p < 0.01$ ) greater than running.

triathlon, the 3.8 km swimming, 180 km cycling, and 42 km running represent on average 11.3±0.4, 52.3±1.3, 35.1±1.0% of the total time, respectively.

For both Olympic and Ironman distances, the performance ratios for each mode of locomotion decreased in a curvilinear manner with advancing age (**Fig. 1A, B**). For both distances, there was an interaction of age and mode of locomotion ( $p < 0.001$ ). For Olympic distance, the performance ratio was significantly different ( $p < 0.01$ ) from the previous age group, from age group 40 for swimming, from age group 50 for running, and from age group 55 for cycling, respectively. Cycling performance ratio remained significantly ( $p < 0.01$ ) greater than swimming from age group 40 onwards, and from age group 45 cycling performance ratio remained significantly ( $p < 0.01$ ) greater than running. For Ironman distance, the performance ratio was significantly different ( $p < 0.01$ ) from the previous age group, from age group 45 for swimming and running, and from age group 50 for cycling. Cycling performance ratio remained significantly ( $p < 0.01$ ) greater than swimming from age group 45 onwards (except for age group 70), and from age group 50 cycling performance ratio remained significantly ( $p < 0.01$ ) greater than running.

Comparisons of age related declines in swimming, cycling, running and total performance for Olympic and Ironman triathlons are presented in **Fig. 2**. There was an interaction ( $p < 0.001$ ) of age and distance for cycling, running, and total event times, but not for swimming times. Age-related declines in performance were less ( $p < 0.01$ ) pronounced for Olympic compared with the Ironman distance for cycling, running and total time from the following age groups and above: 55, 50, and 55, respectively.

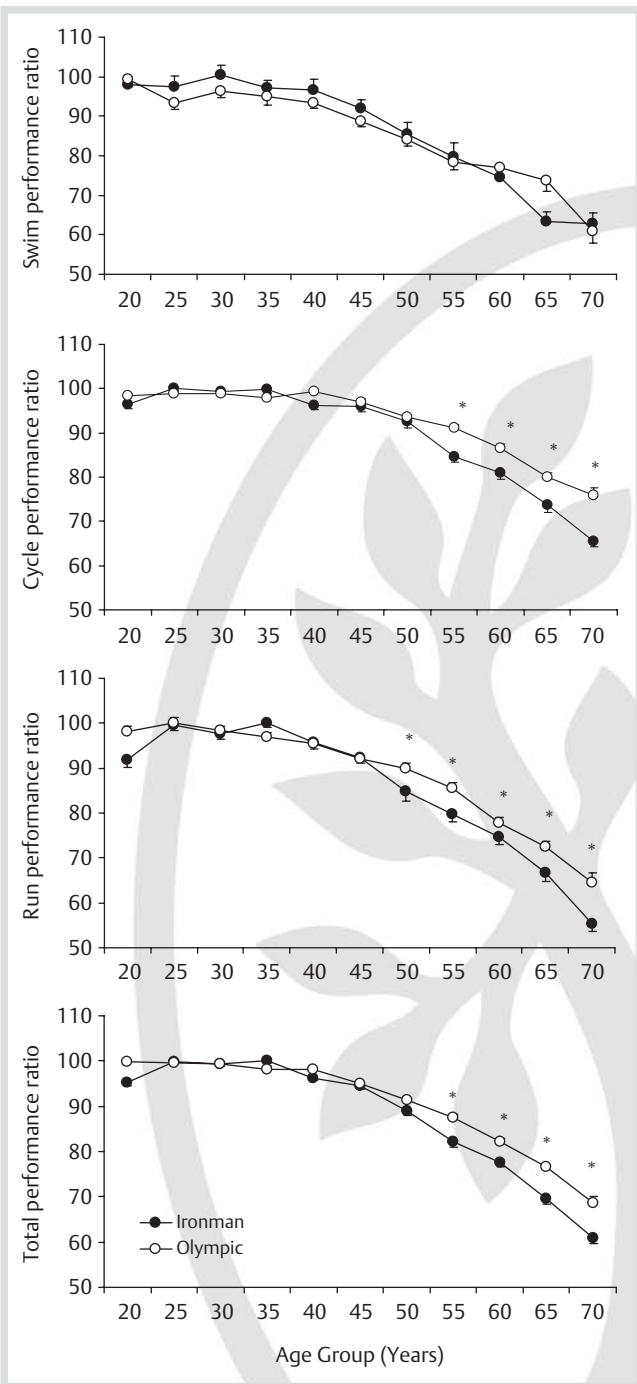
## Discussion

The main findings of the present study were i) a reduced age-related decline in cycling performance compared with running and swimming performances for both Olympic and Ironman distance triathlons, and ii) a smaller effect of age on cycling and running performances for Olympic than for Ironman distance triathlon, but a similar age-related decline in swimming performance for Olympic and Ironman distance triathlon.

### Methodological considerations

With endurance events, the environment (temperature, humidity, precipitation) affects the outcome of the results. For Olympic triathlons taking place in Lausanne (2006) and Hamburg (2007), the temperature was around 20°C and 15°C, respectively, whereas during the Hawaii Ironman in 2006 and 2007, the temperature was around 30°C. Thus, the hotter conditions for the Ironman triathlon may have more greatly affected performance than for the Olympic triathlon. However, by normalizing the individual time performance by the mean time performance of the top 10 of the best performing age groups for both distances, the influence of environment was minimized when comparing Olympic and Ironman triathlon performances. Moreover, the results showed that the mean time performances of the best performing age groups for each individual discipline were very similar between 2006 and 2007 for both Olympic and Ironman triathlons.

The present paper focuses on the performances of male triathletes only. Potential differences in age-related decline in endurance performance between male and female may also occur, so it could be interesting to verify if similar results are obtained for



**Fig. 2** Age-related declines in swimming, cycling, running and total performances for Olympic and Ironman triathlons (mean ± SE). There was no distance effect for swimming performance. However, age-related decline in cycling, running, and total performance was less pronounced for Olympic triathlon. \*: p < 0.01: Significantly different from Ironman triathlon for the same age group.

female triathletes. However, for Ironman triathlon, data for female triathletes older than 65 years of age are limited. Moreover, unpublished data from our laboratory suggest that similar findings are observed for female triathletes i.e. reduced age-related declines in cycling performance compared with running and swimming performances and a greater magnitude of age-related decline in cycling and running performance for the Ironman triathlon than for the Olympic triathlon.

The present data do not include performance of elite/professional triathletes. At the world Olympic triathlon championships, elite triathletes raced a different course with different rules (drafting allowed for the elite athletes and forbidden for the age groupers). At the world Ironman triathlon championships, elite triathletes raced the same course but started 15 min before the age groups (drafting forbidden for both the elite and age groups).

**Age related differences in locomotion mode**

For both Olympic and Ironman triathlons, there was a lesser age-related decline in cycling performance compared with running and swimming performances. Bernard et al. [5] had previously reported a less pronounced age-related decline in cycling performance than the other locomotion modes but for Olympic triathlon only. Thus, the question of whether there was a better maintenance of cycling performance or a greater decline in running and swimming performances with advancing age could be raised. One explanation for the different age-related declines in cycling and running may involve the mechanical power required by these disciplines. Mechanical power output in running depends on the velocity ( $P=k.v$ ) while it depends on third power of velocity in cycling ( $P=k.v^3$ ). If we assume that the changes in aerobic capacity (e.g.  $VO_{2max}$ ) with age are directly related to the decline in mechanical power, a similar reduction in power output for running and cycling with advancing age would induce a lower reduction in cycling velocity than running velocity. This may explain, in part, why the magnitude of the decrease in cycling performance with age was less than that for running. Running also involves stretch-shortening cycles (SSC) with eccentric muscle actions, while cycling is a non weight-bearing activity with dominant concentric muscle actions. Fast twitch fibres, however, atrophy more than slow twitch fibres with age [10]. Because fast twitch fibres seem more susceptible to damage than slow twitch fibres during SSC, the greater reduction in running performance compared with cycling could therefore be related to muscle typology changes with age [30]. However, the changes in muscle fibre type distribution i.e. the percentage of type I muscle fibres with advancing age seem less pronounced in well-trained masters athletes compared to untrained older adults [29]. Moreover, in terms of muscle damage, although some animal studies have shown that recovery from eccentric exercise-induced muscle damage is lessened in older subjects compared with the young, the results from humans studies are not as clear [7]. Results might differ among muscle age groups but there is no evidence that the muscles of older triathletes would be more susceptible to muscle damage than muscles of young triathletes.

Findings for competitive long-distance runners indicate that the decline in running times parallel the age-related reductions in maximal oxygen uptake and in lactate threshold [11,20]. The contributions of these respective physiological factors to age-related declines in cycling performance, however, are unknown at present. Indeed, very few studies are available on the effect of age on cycling performance. Balmer et al. [1,2] recently characterized the decline in maximal oxygen consumption and maximal aerobic power with age in cycling. However, the relative intensity expressed as a percentage of maximal heart rate or maximal oxygen uptake as well as economy was not affected by age during a ~20 min time trial. Thus, it is tempting to speculate that the lesser decline in cycling performance with advancing age could be due to a lesser reduction in lactate threshold and/or economy compared with running.

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An alternative explanation for the smaller age-related decline in performance in cycling compared to running is the maintenance of a relative greater exercise training “stimulus” in cycling. It has been shown that an overall reduction in the exercise training “stimulus” occurs with advancing age [21,26]. In running, the decline in exercise performance with age has been partly attributed to an increased incidence of orthopedic injuries, which would limit running training volume of many older athletes [20, 12]. It is possible that cycling performance was influenced to a much lesser extent by this factor. Moreover, it has been shown that protein synthesis rate is decreased in older subjects compared with young subjects that could limit the running training volume in older triathletes where muscle damage occurs [27]. With advancing age triathletes would tend to spend more training time on cycling than running, as a consequence of changes in physical factors (e.g. increased prevalence of injuries). Unfortunately, change in training volume in the three disciplines with age was unknown in the present study. Further prospective studies would be necessary to quantify the changes in training volume in triathletes with age because training history is an important aspect of performance status at an older age.

For both Olympic and Ironman triathlons, swimming and running performances decline in a similar manner until 65–70 years. This result differs from those of Tanaka and Seals [25] who found a smaller reduction in swimming than in running performances with advancing age. These authors suggested that the two hypotheses to explain this task-specific difference were a greater dependence on biomechanical techniques for swimming than for running, and a greater prevalence of orthopaedic injuries during running with advancing age, which could limit the training volume compared with swimming [9]. However, Tanaka and Seals [25] analysed the changes in swimming performance with advancing age for distance  $\leq 1500$  m in swimming pool conditions that differ greatly from open-water conditions in triathlon. Open-water conditions might include currents and waves especially in the ocean (3.8 km swim at Hawaii Ironman); moreover in triathlon, the swimming start is a mass start, a stressful situation in which triathletes may become disturbed, especially when they are not very good swimmers. In addition, triathletes may not swim at the maximal speeds because they have to cycle and run following the swim. All these factors might explain a greater reduction in swimming performances with advancing age in triathlon compared to conventional swimming in the pool and therefore the absence of differences between changes in running and swimming performance with advancing age in triathlon.

#### Task duration and age-related changes in performance

Age-related changes in swimming performance were not influenced by task duration; the magnitudes of decreases in swimming performance were similar for Olympic versus Ironman triathlon. Swimming is the first discipline during a triathlon, so triathletes perform it without suffering from accumulated fatigue in contrast to the cycling and running disciplines. On average, swimming performance declines by ~15% at 50 years old, and reaches ~38% by 70 years of age. Previous studies showed no effect of task duration for shorter swimming distance events. For example, Tanaka & Seals [24] found no significant differences in the magnitude of performance decline with age (~32% at 70 yrs age) among distance events ranging from 100–1500 m in pool. The lower performance decline observed by these authors for the same age (70 yrs old) compared with tri-

athlon data might be due to the differences between the water conditions: calm in swimming pool versus stochastic in open water for triathlon.

In contrast to swimming, the magnitude of the declines in cycling and running performances with advancing age at Olympic triathlon was less pronounced than at Ironman triathlon. It is not clear why task duration in triathlon exerts an influence on age-related declines in cycling and running performance. For the 70–74 yrs age group, the finish time was ~3 h for the Olympic triathlon versus ~15 h for Ironman triathlon. Certainly the Ironman triathlon induces greater neuromuscular fatigue in cycling and running compared with Olympic triathlon [15, 18]. Furthermore, muscle damage during 10 km run of Olympic distance is limited compared to that occurring during the Ironman marathon [17,23]. Endurance exercise increases the use of endogenous fuels to provide energy for working muscles. However, resting muscle glycogen concentration is diminished in older humans [6], and hepatic gluconeogenic and glyconeogenic capabilities have been found to decline with age [19]. Older subjects oxidize more glucose and less fat during moderate intensity exercise [16]. This shift in substrate use is presumably caused by age-related changes in skeletal muscle, including decreased skeletal muscle respiratory capacity. Similarly, Sial et al. [22] found that compared with young adults, fat oxidation was lower in older adults during endurance exercise performed at either the same absolute or relative intensity. Changes in substrates availability and utilisation with advancing age could explain in part the task duration effect on triathlon performances at least in cycling and running.

#### Conclusion

▼ This cross-sectional study found that the age related declines in cycling performance are less than in swimming and running at both Olympic and Ironman triathlons. These findings indicate that age related declines in endurance performance are specific to the locomotor task although the cause for the task-specificity is not locomotor task clear. In contrast to swimming, the magnitudes of age-related declines in cycling and running performance for the Ironman triathlon are greater than for the Olympic triathlon, suggesting that task duration exerts an important influence on the age-associated changes in triathlon performance. Further studies examining the changes in training volume and physiological characteristics of older triathletes are required to better understand the age-associated changes in triathlon performance and will provide valuable information for understanding the way to maintain physical capacity and performance with advanced age.

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