Jacobs Journal of Sports Medicine

Review Article

Trends in The Age of World Championship Medallist Swimmers in The Past Forty Years

[1]Ildikó Balatoni, [1]László Csernoch
[1]Department of Physiology, University of Debrecen, Debrecen, Hungary

**Corresponding author:* Dr. László Csernoch, Department of Physiology, University of Debrecen, Debrecen, Hungary.

E-mail: csl@edu.unideb.hu, Phone: (52) 411-600 / 54575.

Received Date: 11-01-2018

Accepted Date: 11-29-2018

Published Date: 12-10-2018

Abstract

Different athletes reach their maximum performance at different ages. Numerous research studies have attempted to determine the time interval in athletes' lives when this peak performance can be expected. Here the age distribution of the medallists competing at the 16 most recent World Aquatic Championships was examined by comparing the various individual swimming events. In addition, the possible trends, along with the data of men and women competing in the same events were also assessed searching for differences between genders. Linear regression was applied to examine the trends of ages in the various sport events using clustering for grouping the events. The Kolmogorov-Smirnov test was applied for checking probability distributions while Moses extreme reactions test was used to identify extreme values. Although the ages of medallists vary rather greatly (13-35 years), the average age is in a relatively narrow range (20.2-22.9 years). The age distribution generally proved to be symmetrical, with few extreme values, at the same time a negative skewness could be observed in the case of short-distance breaststroke (50-100 m), which suggests a high probability of ages below the average. Significant trend could be detected in most of the events with a rising tendency in age. The average age of men was higher in all events except for the 1500 m freestyle. While the age of medallists in shorter distance events proved to be significantly lower in the case of men, the medallists of longer distances were found to be older in the case of women. Differences in the various swimming styles draw the attention to the fact that this aspect must also be considered when drawing conclusions regarding age and gender.

Keywords: Age; Gender; Medallists; Swimming; World Championship; Trend

Abbreviations

JWC- Year of the World Championship,

WAC -World Aquatic Championship

Introduction

Athletes who wish to build a career at an international standard could profit greatly from knowing when they would reach the height of their performance and how long they could maintain this maximum. Trainers and competitors could more accurately and realistically plan and build an athlete's career in the possession of this knowledge, including training and competition programme as well. The physiological parameters that determine an individual's performance naturally change with age; they are limited at birth and gradually increase to a peak then decrease to reach zero at death [1,2]. Although it seems obvious that both men and women reach the maximum of their physical development in their twenties, limited number of scientific studies have dealt with the question of age dependence of performance and its peak among elite athletes in various sports.

Previous research in this field incorporated essentially two different methods to examine this issue. One alternative is to track the changes in performance (e.g.: time required for running a given distance in case of runners or rating in case of chess players) of individual athletes according to age, while the other is to examine the age of athletes achieving outstanding results at major international competitions. Early research in the former case approached the age dependence of performance with a quadratic function [3]. In the light of more recent research, the age dependence can be described as a sum of a double exponential function where the first exponential characterises development at early age while the other exponential the decrease accompanying advancing age [4]. Based on research by the latter authors, which involved an analysis of 600 athletes' careers, the average age connected to maximum performance is 26.1 years. It is important to emphasize, however, that the age associated to maximum performance differs significantly according to various sport events.

The second aforementioned method seems more suitable for the analysis of differences among various sports. The first such comprehensive work belongs to [5] who examined the age of gold medallists of the modern Olympic Games between 1896-1980. Their most important finding was that though the average speed of runners increased over the years, the average age of winners did not show any significant changes. At the same time, differences were found both between genders and the various distances. The latter findings have since been confirmed by a number of publications. In general, it was concluded that women reach their best performance at a younger age than men do, while competitors in longer distances (10.000 m, marathon) reach their top performance at older ages [6-8]. However, more recent research has gone further to determine that women competing in middle- and long-distance running reach the maximum of their performance at older ages than men [9]. In addition, the age of Olympic medallists was shown to change significantly in certain sports as the year's progress [10,11].

Literature in this field generally focuses on athletics and swimming. It is interesting to see, however, that in almost all cases results related exclusively to freestyle are analysed within swimming [8, 12-14] and only a few studies deal with the other swimming styles [15].

In our research, considering the aforementioned, we examined whether the trends observed in the case of Olympic medallists can also be confirmed regarding the medallist swimmers of World Aquatic Championships (WAC). Furthermore, we analysed the age distribution of the medallists by comparing, on the one hand, the various events, while on the other hand, the data of men and women competing in the same events.

Materials and Methods

We collected the age of athletes placed in the top 3 of all individual events in swimming at the WAC between 1973 and 2015 from an Internet database and analysed them with statistical methods (SPSS; IBM Corporation), placing the emphasis on differences among genders and trends observable among various swimming styles.

In order to examine the trends in ages, a linear regression in the form of

$Age = \beta * YWC + E$, Eqn. 1

were fitted, where *Age* denotes the age of the medallist, *YWC* denotes the year of the AWC, while *E* is a random distribution variable; significant trend was assumed if $p<0.05$.

Grouping the events in the various swimming styles was performed by applying a two-step clustering based on age as scale-type variable, and then on distance as a categorised variable. Women and men were considered together during clustering. The Kolmogorov-Smirnov test was applied to check for probability distribution comparing age distributions among various events and between genders in a given event as well as between genders for a given distance. The most important statistical parameters of the age distribution in individual events (average, standard deviation, skewness, and kurtosis) were also calculated. We applied the Moses extreme reactions test to identify extreme values within the sports events and genders. ANOVA analysis was applied according to genders and sports to compare average age in the various distances. Comparison according to pairs was performed by applying the Least Significant Difference Post-Hoc test as the homogeneity of variance was met in all cases based on the Levene's test. Data, where necessary, are presented as the mean ± standard deviation (SD) of the mean.

Results and Discussion

Trends Detectable in The Age of Competitors

First we examined whether any trend can be detected in the age of the medallists, separately for the two genders. To this end the age of the medallists was plotted as a function of YWC (as in Figs. 1 and 2) and the data points were fitted by a linear regression (*Eqn. 1)*.

When the data were analysed separately for each individual event, significant correlation and positive trend (β values in range of 0.072 and 0.155; corresponding to an increase of 3.0 and 6.5 years in age from 1973 to 2015) between the age of the medallists and YWC was found for most of the events independent of the gender. Examples for female 200 m and male 100 m breaststroke are presented in Fig. 1. The events where significant correlation could not be identified were female 50 m backstroke, breaststroke, butterfly, and 1500 m freestyle, while male 50 m freestyle, breaststroke, and 800 m freestyle. It should be emphasised here that all these latter events were introduced at the 2001 WAC, thus the analysed time-window is significantly smaller than for most of the other events.

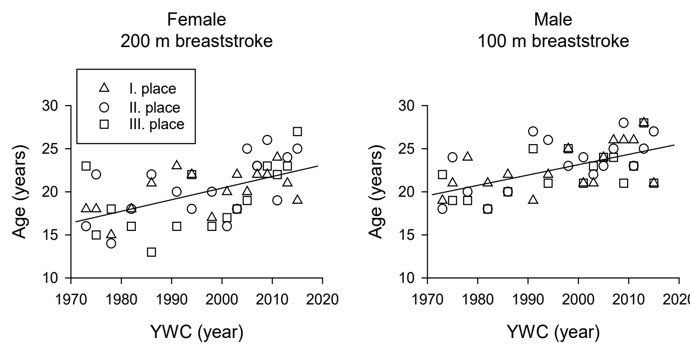

Figure 1: Trends in the age of World Aquatics Championship (WAC) medallists. The age of all female or male medallists competing in 200 m (female) or 100 m (male) breaststroke on a given WAC were plotted as a function of the year of WAC (YCH). Data points were fitted with a linear regression ($\beta = 0.134$, $r^2=0.304$ and $\beta = 0.120$, $r^2 = 0.340$, for females and males, respectively).

From the events that were present in all analysed WAC and showed a significant correlation, the lowest r^2 values were detected in case of female 100 m breaststroke (0.173) and male 100 m freestyle (0.124). Generally, as distances increase so do the β and r^2 values, i.e., an increasingly stronger correlation can be detected between the age and the YWC as distance increases.

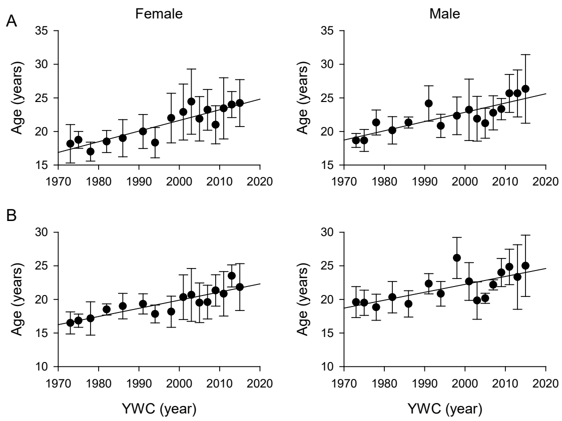

Figure 2: Trends in the age of World Championship (WAC) medallists in different swimming styles. The age of all female (left panels) or male (right panels) medallists competing in individual butterfly (A) or medley (B) on a given WAC were averaged and plotted as a function of the year of WAC (YCH). Data were fitted with a linear regression (females: β=0.161, r^2 = 0.292 and β = 0.122, r^2 = 0.323, for butterfly and medley, respectively; males: β = 0.141, r^2 = 0.280 and β = 0.118, r^2 = 0.235, for butterfly and medley, respectively). Data points represent mean±SD.

Importantly, if everyone competing in the same style were analysed together – i.e., ignoring the distance of the race – a clearly increasing trend was detected in all cases of both female and male swimmers (Table 2).

Overall, on the one hand, our results here support the correlations received regarding the age of Olympic medallists [10, 16,17], and at the same time complete it with data regarding swimming styles. On the other hand, the data are in good agreement with the results regarding Swiss freestyle swimmers published by [13].

Examination of Age Distribution of Medallists in Short and Long Distance Events

A two-step clustering of the individual events – based on distance and age – was performed and three clear clusters – short (50 m, 100 m), medium (200 m, 400 m), and long (800 m, 1500 m) distances – were identified. Women and men were jointly considered during the clustering, however, the established cluster structure was found to be independent whether women and men were considered separately or jointly. We also performed the clustering by forcing to have only two clusters, since we were interested to see whether the 400 m medley would end up among the long distance events or not. Interestingly, in the two-cluster solution, 200 m butterfly, medley, breaststroke, and backstroke as well as both 400 m events fell into the long-distance cluster. Although the two-cluster solution was, consequently, disregarded, it suggested that the age distributions for medium and long distances might be similar.

This close resemblance in the distributions was confirmed by the Kolmogorov-Smirnov test for probability distributions as there was a significant difference in the

Table 1. Swimming styles, where significant trend was be observed regarding the age of the medallists.

Gender	Style*	r^2	β
Male	freestyle	0.200	0.112
	backstroke	0.335	0.146
	breaststroke	0.206	0.106
	butterfly	0.280	0.141
	medley	0.235	0.118
Female	freestyle	0.275	0.156
	backstroke	0.270	0.143
	breaststroke	0.252	0.130
	butterfly	0.292	0.161
	medley	0.323	0.122

* All medallists competing in the given style were considered.

Table 2. Main statistical parameters of the age distribution of the individual swimming styles.

Event*	Average (year)	SD (year)	Skewness	Kurtosis
50 m freestyle	21.91	3.867	0.414	-0.293
100 m freestyle	21.48	3.506	0.024	-0.217
200 m freestyle	20.70	3.255	0.886	0.909
400 m freestyle	21.59	3.576	0.405	0.008
800 m freestyle	22.28	3.356	0.357	0.132
1500 m freestyle	21.15	4.062	0.836	0.623
50 m backstroke	22.38	3.824	0.319	-0.584
100 m backstroke	21.82	3.638	0.343	-0.672
200 m backstroke	21.11	3.496	0.171	-0.338
50 m breaststroke	21.94	3.767	-0.376	-0.826
100 m breaststroke	21.45	3.327	-0.035	-0.494
200 m breaststroke	21.65	3.401	0.340	1.536
50 m butterfly	21.04	2.753	0.405	-0.355
100 m butterfly	22.91	3.945	0.375	-0.508
200 m butterfly	21.82	3.816	0.686	1.120
200 m medley	20.15	2.993	0.582	-0.290
400 m medley	21.12	3.605	0.678	0.368

* All medallists (females and males) competing in the given event were considered.

age distribution between short and medium distances on the whole (p=0.002), while there was none in the age distribution of medium and long distances (p=0.335). Separately examining the different styles and distances, the age distribution of, e.g., 400 m medley was found to be significantly different from that of the 100 m butterfly (p=0.010), the 200 m breaststroke (p=0.038), and the 100 m backstroke (p=0.095) but not from the 1500 m freestyle (p=0.493).

As swimmers in breaststroke generally do not compete in events of other styles, the 50 and 100 m breaststroke were examined separately. Nonetheless, the age distribution of the medallists in 50 m breaststroke did not differ significantly from the other events, however, the distribution is least comparable (p=0.128) to that of butterfly and most comparable to that of backstroke (p=0.847). Similarly, the age distribution of the 100 m breaststroke did not differ significantly from the other events, with the age distribution being least comparable to freestyle (p=0.356), and most comparable to backstroke (p=0.999).

Based on the age distributions the highest averages were found for the 100 m butterfly, 50 m breaststroke and backstroke, as well as the 800 m freestyle, while the lowest for the 200 m freestyle, backstroke, medley, and 50 m butterfly events (Table 2). On the other hand, the standard deviation is the highest for the 100 m butterfly and 1500 m freestyle events. Interestingly, based on the skewness, the 50 and 100 m breaststroke differ from the others as the skewness is negative, which refers to the fact that the likelihood of ages smaller than the average is higher than those that are greater than the average. The high value of kurtosis in case of the 200 m breaststroke, 200 m butterfly and 200 m and 1500 m freestyle might refer to a large number of outstanding values.

Examination of Differences in The Age Distribution Between Genders

The examination of the age distributions showed, in general, that there are significant differences between the genders for short and medium distances (p=0.001) while no significant difference can be seen at long distances (p=0.162).

Table 3: Average age of medallists competing at short, medium and long distances

Distance	Men*	Women*	p[§]	Comparison	p[&] (Men)	p[&] (Women)
short	22.82 (3.42)	20.93 (3.60)	<0.001	short-medium	0.009	0.011
medium	22.14 (3.15)	20.19 (3.54)	<0.001	medium-long	0.815	0.013
long	22.04 (3.17)	21.38 (4.27)	0.294	long - short	0.007	0.349

* Values in brackets give the Standard deviation

§ Significance values were calculated comparing data from males and females

& Significance values were calculated comparing different distances as indicated

In particular, when comparing the age distributions of female and male medallists according to events, significant differences were found between the genders in most of cases, except for 50, 200, 400, 1500 m freestyle, and 50, 100 m butterfly. In other words, the age distributions did not differ in almost all freestyle and short distance butterfly events. The most significant difference in the age distribution of medallists was detected in the 400 m medley (p<0.001), but there was also very significant difference in the 100 and 200 m backstroke (p=0.001 and p=0.003), as well.

The overall span of distributions and the presence of extreme values were also examined by applying the *Moses test of extreme reactions* in case of the latter. No difference was detected between men and women regarding the span of the distributions in case of 50-800 m freestyle, 50-100 m backstroke, 100 m breaststroke, and 100 m butterfly, while both the span and the likelihood of occurrence of extreme values were different in the other events. Actual extreme values were detected for men in the 200 m breaststroke and the 200 m butterfly, as well as the 200 m and 1500 m freestyle, while in case of women in the 1500 m freestyle. All these refer to the fact that, on the one hand, maximum performance is reached in a similar age-window for both genders (see also Allen and Hopkins, 2015). On the other hand, there are clear differences among the various swimming styles [18]. A striking conclusion is, however, that from these aspects, freestyle is the most alike for men and women. This observation highlights the fact that more attention is required in the future for the other swimming styles in similar studies.

In order to decide whether the average age of medallists in different distances – as identified by the cluster

Table 4: Average age of medallists competing at various distances

Distance[$] (m)	Gender		p
	Men*	Women*	
50	24.86 (3.38)	23.31 (4.03)	0.002
100	22.55 (3.07)	20.58 (3.54)	<0.001
200	22.11 (3.09)	19.94 (3.15)	<0.001
400	21.01 (2.79)	19.58 (3.32)	0.001
800	22.04 (2.49)	19.57 (3.17)	0.001
1500	20.79 (3.01)	21.79 (3.93)	0.235

[$] All styles were included

* Values in brackets give the Standard deviation

analysis – differ or not, an ANOVA test based on genders and sports was applied. The pairwise comparison was performed by applying a Least Significant Difference Post-Hoc test as the homogeneity of variances was fulfilled in all cases.

The average age of men competing at shorter distances was found to be significantly higher than those competing in medium and long distances (Table 3). In contrast, in case of female medallists, the average age was significantly lower at medium distances as compared to short and long distances (Table 3). In parallel, significant differences could be detected between genders at short and medium distances, as the average age of male medallists was higher (Table 3).

When examining the various distances, independent of the style, we found that – except for the 1500 m, where the difference was not significant (although the average age of female medallists was slightly higher) – the average age of male competitors was significantly higher (Table 4).

Conclusion

The age of medallists in all individual swimming events from 16 World Aquatic Championships were analysed, seeking the differences in age distributions among the various events and between genders, along with possible observable trends.

Although the best performances occurred in a relatively narrow age-window, there are a number of swimming styles and distances, where extreme values are typical. It was an interesting observation that the age distribution of short distance breaststroke swimmers showed a negative skewness referring to the presence of a large number of successful younger than average swimmers. Although it is a general belief that the age of the medallists does not change significantly in the various swimming styles, a positive trend was observable for both male and female competitors in most styles and distances. Male medallist in world championships are typically older than females, the only exception being the 1500 m freestyle. This could be due to the fact that world championship competitions in this distance for women have only been held since 2001. Interestingly, when comparing the various distances, the age of male medallist competing in short distances proved to be the highest, while for women this was true for the long distances.

Our observations highlight the fact that the various swimming styles reflect different characteristics in the age distribution of world class swimmers thus further analyses are required in this direction.

Acknowledgements

The publication was supported by the EFOP-3.6.2-16-2017-00003 project. The project is co-financed by the European Union and the European Social Fund.

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