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The Analysis of the Impact of Gender and Age in Competitive Sports: A Case Study of Olympic Swimming Finals from 2012 to 2024

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Abstract. The top swimmers' improvements are impacted by training changes, athletes' demographic factors, and physical traits. Knowing the right factors, trends in performances, it would be easy to develop better training techniques and allow for athletes to perform at their peak level of performance. The research takes a full survey on how the sex and age would influence the swimming performance at Olympics held from 2012-2024, it studies the performance patterns under different stroke types and various distance segments. Top 8 finalists in every event had their data put through tough stats scrutiny, t-tests and ANOVA tested progress and age changes too. Also from the results it can be seen that the female and male swimmers had similar rates of progress for performance across the Olympic cycle There is no significant difference in performance between gender during an Olympic cycle. But there are some interesting exceptions to find in certain events that show stalling in men's 100m free and women's 200m fly during certain time periods. Looking at the age analysis from the results, it was found that there is a general increase of the age from the competitors, but there is more swimmers below age in endurance swims while more older age groups won the sprints like the 50m Freestyle. The Olympic year wasn't really tied up with any strong patterns in age trends, but it looks like the kind of stroke people swam and how far they went were very important for figuring out the differences in ages between the racers. These results give us detailed ideas about how the mix of gender and age affects elite level swimmers, which could be used to improve how they train and find new, talented swimmers for races.

Keywords: Olympic swimming, Age and Gender Analysis, Performance Progression Trend

1. Introduction

In modern times, more studies have tracked swimming performance to analyze its progression trends and human limits. The majority of the scientists were trying to search for the evolution of performance metrics (times and ages) and how athletes continuously push the boundaries of human capabilities [1]. Peaking performance is a significant challenge for swimmers during the Olympic Games [2]. Any valid findings are important for swimmers to achieve their peak performance and for their support team to build strategies [2]. The role of athlete demographics, particularly age and gender as key factors influencing sports performance, and scientists were growing interest in understanding whether these variables contribute to performance outcomes in competitive sports.

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This study focuses specifically on the impact of gender and age on Olympic swimming performance, finding the relevant data patterns that can be considered in training, physiology, and even societal perceptions regarding gender and age in competitive sports. The research examines the data sets of Olympic swimming finals to investigate how gender and age influence swimming performance across Olympic years from 2012 to 2024. The boarder implications of understanding their trends such as how this data can inform future athlete training, development strategies, and the selection of younger versus older athletes in different events.

This research carries out meticulous statistics to study the gender-based performance trends, and compares the progress, peaks, plateaus of boys' and girls' swimmers within a variety of different Olympic cycles. Also analyzing age effects for swimming and see whether age of the candidates in the Olympic finals has much effect on each type of stroke and each distance over time. The study went on to search for variations in age distribution between Olympic years, find times. To make things more specific, I separate my study into stroke and distance and check if some events have even older age differences than others, to learn about those important numbers for top swimmers.

Performance progression has been tracked and analyzed in sports science since last century, in an attempt to enhance and predict athletic performance. Many studies have approved that swimming performance has been continuously progressed in the past two decades [3,4]. In 2024, Patoz's mathematical analysis predicted record-breaking performance in freestyle for the 2024 Olympic Games, the predication model indicates that several freestyle events had the potential of record-breaking [5]. In result, the male of 100m freestyle set the new World record in the 2024 Paris Olympics which matched the prediction.

The aging of elite athletes is always a key factor in training development and peak performance [1]. The evolution of aging is a major challenge in peaking performance for athletes [6]. In 2012, Berthelot indicated the age of 21 years old swimmers would achieve their peak performance [6]. However, the change of age in different swimming events varied in the past decade. Few scholars reported that the age of swimmers was increased in the modern time [3,7]. In 2017, Mazzilli revealed the age of swimmers continuing increase for both men and women who won medals in 2 or 3 different Olympic games [7], while Konig reported that there were changes in the age of swimmers in performance in different strokes and distance for both women and men at World championships and Olympic Games [3]. A rise of age in performance for females has been reported in swimming events: 100m and 400m freestyle while men's age tended to be stable [8].

As many studies have conducted detailed analysis across multiple World class level competitions and Olympic cycles for swimming, particularly with a focus on investigation of changes in age and performance trend [2]. However, there were very few discussions on the gender impact of competitive swimming. Therefore, it is necessary to continuously find a deep understanding of age and gender factors in swimming performance progression that will help develop more scientific training programs from coaches, and allow athletes reach to maximum performance and approach or exceed human limits.

2. Research method

2.1. Data sources and collection methods

The datasets were collected from the Olympic Swimming Official Record Book of 2012, 2016, 2020 and 2024. The research time frame was chosen between 2012 to 2024, because the technology brought a "super-suit" that enhanced swimmer's performance tremendously in 2008 Beijing Olympic, but it was banned by FINA in the beginning of 2010. The top 8 Olympic swimmer's performance and age (finalists) from each event were selected. A total of 640 swimming final performances were collected (320 from females, 320 from males). The events were included and analyzed: 50m freestyle, 100m

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freestyle, 200m freestyle, 400m freestyle, 100m breaststroke, 200m breaststroke, 100m backstroke, 200m backstroke, 100m butterfly, 200m butterfly.

2.2. Data measurement and inspection methods

The finalists' performance, age mean, and progression rate were assessed with a t-test for the difference between men's and women's progression of performance across four Olympic periods in each stroke and distance. The average age of 2020 finalists were one year older because the 2020 Olympics was postponed to 2021. The two-way ANOVA was implemented to gain a further understanding of the impact of variable factors on performance progression. A P-value results in less than 0.05 sets as the rejecting the null hypothesis for statistically significant differences between men's and women's performance. The age of Olympic swimmers' data variation was analyzed by applying two-way ANOVA to examine the effect of the Olympic year and different stroke and distance on ages. The program of Python was implemented to analyze both T-Test and ANOVA.

2.3. Research hypothesis

This study hypothesizes that both women and men swimming performance continuously improve in the past decade, and there is gender difference of progression trends in Olympic swimming. Another hypothesis of this study is the age of Olympic swimmers continuously increased across the four Olympics from 2012 to 2024, however, there is a significant difference between each stroke and distance.

3. Research result

3.1. Impact of the gender in swimming performance across the Olympics

The progression rate indicates that most of swimming performance increased across the Olympics (2012-2024) for both men and women (Table 1), except 100m freestyle, 200m butterfly for male and 200m backstroke and 200 butterfly for females from 2012 to 2016. From 2016 to 2020, both 400m freestyle and 200m backstroke performance decreased for male and women's 200 butterfly continuously decreased for two Olympic periods. There are more performances that were not improved from the 2020-2024 Olympics: 200m freestyle, 100, backstroke, 100m and 200m breaststroke for men and 100m backstroke, 200m breaststroke, and 100m butterfly for women.

The performance of gender of this study shows that men and women gain similar progression trends in each stroke and distance from 2012 to the 2024 Olympics (Figure 1).

The t-test gave the results that there is no significant difference between women and men performance progression across the Olympic years. All tested p-values were larger than 0.05, which means that it failed to reject the null hypothesis ($p>0.05$) (Table 2).

Table 1. Olympic swimming finalist progression rate (2012-2024)

Stroke	Distance	20212-2016		2016-2020		2020-2024	
		Men	Women	Men	Women	Men	Women
Freestyle	50	-0.05	-0.90	-0.32	0.00	-0.37	-0.17
Freestyle	100	0.19*	-0.91	-0.67	-0.83	-0.21	-0.08
Freestyle	200	-0.11	-0.98	-0.58	-0.10	0.34*	-0.01
Freestyle	400	-0.57	-0.43	0.03*	-0.16	-0.26	-0.55
Backstroke	100	-0.90	-0.46	-0.46	-0.80	0.13*	0.34*
Backstroke	200	-0.46	0.50*	0.63*	-0.85	-0.51	-0.10
Breaststroke	100	-1.04	-0.21	-0.64	-0.93	1.16*	-0.06
Breaststroke	200	-0.57	-0.01	-0.13	-0.47	0.63*	0.64*
Butterfly	100	-0.77	-0.81	-1.23	-0.88	-0.12	0.59*
Butterfly	200	0.46*	0.19*	-0.30	0.30*	-0.88	-0.33

*Progression rate was not improved by Olympic swimmers

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Table 2. The paired t-test results of stroke and distance

Stroke	Distance	T-Statistic	P-Value
Freestyle	50	0.29	0.80
	100	1.01	0.42
	200	0.63	0.60
	400	0.89	0.47
Backstroke	100	-0.45	0.70
	200	0.05	0.97
Breaststroke	100	0.38	0.74
	200	-0.29	0.80
Butterfly	100	-1.60	0.25
	200	-1.03	0.41

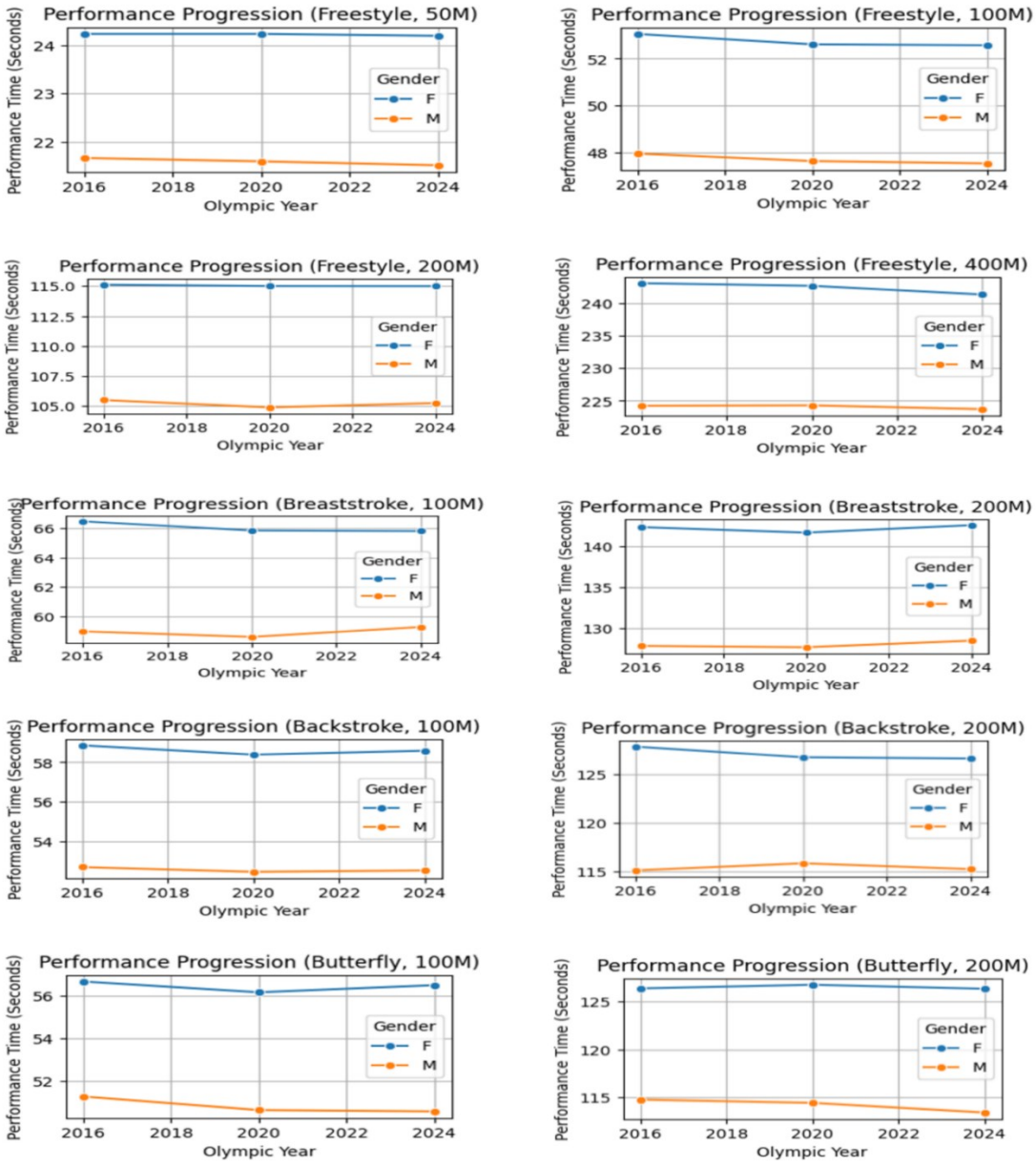

Figure 1. Performance progression for stroke and distance across Olympic games (2012-2024)

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The ANOVA test summarized that Olympic Year has a statistically significant effect on performance progression (p= 0.161), while gender, stroke, and distance, and their interactions do not have significant effects on the performance progression in the model (Table 3).

Table 3. The gender of analysis of variation (ANOVA) summary

	Sum of Squares(ss)	Degree of Freedom (df)	F-Statistic (F)	P-Value (PR(>F))
Gender	0.0132	1.0	0.0522	0.8202
Stroke	0.2796	3.0	0.3679	0.7764
Distance	0.9985	3.0	1.3138	0.2819
Olympic Year	2.2997	2.0	4.5387	0.0161*
Gender:Stroke	0.6091	3.0	0.8014	0.4997
Gender:Distance	0.0709	3.0	0.0932	0.9633

*p-value<0.05

3.2. Impact of swimmers' age across the Olympics

From 2012 to the 2024 Olympics, it can be seen that the average age of finalists in certain strokes and distances change over time (Figure 2). The age of 50m freestyle swimmers is a lot older than all other analyzed strokes and distance, and the event of 200m backstroke, 200m butterfly and 400m freestyle have relatively younger athletes (under 22 years old). The data reveals that all selected events age increased from the past decade, except the 200m butterfly and 400m freestyle.

The ANOVA analysis revealed that there is no significant effect of Olympic year on the age of finalists (p>0.05) (Table 4). And there is no significant interaction between Olympic years and stroke and distance from the ANOVA analysis. However, the analysis indicates that there is significant effect of different stroke and distance on the age factor (p=0.0003).

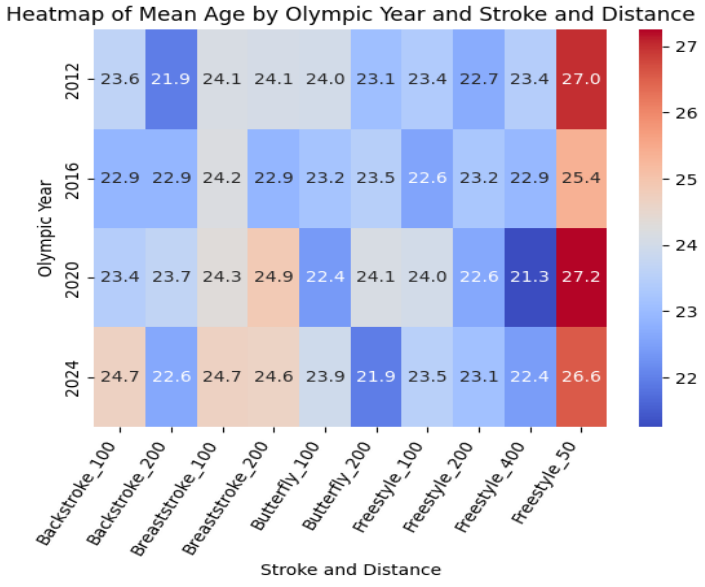

Figure 2. The heatmap of mean age by Olympic year, stroke and distance

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Table 4. The age of analysis of variance (ANOVA) summary

	Sum of Squares(ss)	Degree of Freedom (df)	F-Statistic (F)	P-Value (PR(>F))
Olympic Year	2.6919	3.0	0.3888	0.7616
Stroke and Distance	96.253	9.0	4.6339	0.0003*
Interaction (Olympic Year and Stroke& Distance)	29.7383	27.0	0.4772	0.9768
*p-value<0.05				

4. Discussion

4.1. Impact of gender and swimming performance

As main finding of this study, the progression trend analysis demonstrated that swimming performance improved for both men and women over the Olympic periods, with few exceptions in men's performance in the 100m freestyle and 200m butterfly, and women's performance in the 200m backstroke and 200m butterfly showed no improvement from 2012 to 2016 Olympics. Interestingly, men's performance in the 400m freestyle and 200m backstroke declined from the 2016 to 2020 Olympics, while the 200m butterfly for women continuously decreased across two Olympic cycles. In the 2020 to 2024 Olympic period, more performance dropped in both women and men, particularly in men's 200m freestyle, 100m backstroke, both the 100m and 200m breaststroke, and women's 100m backstroke, 200m breaststroke, and 100m butterfly performance decreased as well. Overall, all performance improved for men compared 2012 to 2024, while women's performance in 200m breaststroke and 200m butterfly did not improve over time.

It is not true even if the different rates of these progresses, the paired t -test still shows no statistical significant difference of progression as a whole from male to female. All compared p-values were larger than the significance threshold of 0.05, thus rejecting the null hypothesis was not possible. The research results show that although there were some changes in each event, the overall progressing trend was the same between the two genders for an amount of 4 Olympic games (2012-2024). The lack of much difference when it comes to how performance progresses goes along with earlier studies pointing out that there is less difference between women and men the distance gets bigger and could be affected by how strong people are as well as things about their bodies [9]. In 2012, Stanua reported similar outcomes, both females and males continue to improve their performance, however the difference between men and women's performance gets smaller with longer swimming distances [10]. It's understandable that there were similar trends for both genders, since it is also possible that advancements in training, technology, and conditioning that could help male and female athletes are the same or equal over time [11].

4.2. Impact of age on swimming performance

The study also revealed trends in the age of Olympic finalists, particularly in relation to specific strokes and distances. While the overall age of athletes increased over the past decades, two events like 200m butterfly and 400m freestyle as exceptions where the age of finalists did not follow this upward trend. Additionally, the 50m freestyle event consistently featured older athletes compared to other strokes and distances, while younger athletes tended to dominate events like the 200m backstroke, 200m butterfly, and 400m freestyle, where finalists were typically under 22 years old. In 1988, Schulz described the change in age is associated with different distances, particularly long distances are associated with younger athletes [12].

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The two-way ANOVA analysis found no significant effect of the Olympic year on the age of swimmers, with p-values greater than 0.05, it's suggesting that the general trend in age across the years does not exhibit meaningful fluctuations. Similarly, there was no significant interaction between the Olympic year, strokes and distances in terms of age impact. However, a significant effect of stroke and distance on age was detected (p=0.0003), indicating that particular strokes and distances are associated with older or younger athletes. This finding is consistent with a few studies suggesting that sprinters (e.g., 50 freestyles) often peak later in their athletic careers compared to athletes competing in longer distances or more technically demanding strokes (e.g., 200m butterfly) [1].

The analysis of age trends also sheds light on the relationship between age and event specialization. While it might be expected that swimmers become younger over time due to the increasing physical demands of elite competition, the data reveal a more complex picture. In some events, particularly sprinting, older athletes maintain their competitive edge, whereas younger athletes excel in more technically demanding or endurance-based events.

The study results provide key data about how gender and age affect how well people swim in the last Olympics. Female and male athletes lack statistically significant differences in progressive performance supports the fact that advances in sports science, training techniques, and technical enhancements appear to benefit male and female athletes equally. This convergence of performances suggest both the females and males are closing in on their respective top ends of human performance at roughly the same rate. And finally, for age trends, there doesn't appear to be a very clear relationship between age and event specialization. Contrary to what one might expect, and in light of the fact that competition at the elite level is more physically demanding, the results show the opposite. Older athletes may still compete in the sprint events like the 50m freestyle event but generally the younger swimmers tend to do better in the technical and endurance events such as 200m butterfly and 400m free. This is against the idea that getting older affects all your swims in exactly the same way; it's like saying all kinds of events have different things your body needs to do and different ways to train if you want to do well. Both the boys and the girls seem to be taking the same path when it comes to reaching their performance highs, which is molded by event details and improvements on the sports field.

5. Conclusion

In this paper, we were trying to examine the impact of gender and age on the Olympic swimming results from 2012 to 2024 in different strokes and various distances. There were some major outcomes from the evaluation that improve our viewpoint on performance advances in elite swimming. Female swimmers and male swimmers also improved quite significantly over the four Olympic cycles though there were certain events that either did not improve at all, like the men's 100m freestyle or women's 200m butterfly when looked at throughout different periods. Although there were these ups and downs, it showed no statistically significant difference between men and women in terms of their performance enhancement. This implies that their performance enhancement trend is relatively the same. This means that advancements in training methods and technology have helped both women and men swim equally as well, making their distance gap smaller. And it showed the part of age in swim performance. Despite the general tendency for the age of Olympic swimmers to increase over the last number of years, some events like 200m butterfly and 400m freestyle showed a decline in age. Besides, the 50m freestyle event always involves older contestants, on the other hands, younger swimmers normally are the mainstay of the more technical or endurance events like the 200m backstroke and 400m freestyle. In general, the results show a complex link between age, gender and swimming. Although a swimmer's progressions were similar to men and women, they differed based on age trend by event. These are really helpful to understand how the body functions and what events

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someone is best at, this could change how we train for and develop swimmers to be able to race better in competitions.

The study can provide us with a great amount of information yet also come with drawbacks The analysis was only done with the finalists, so we can't know about how all Olympic swimmers are doing. Future work could expand the dataset with more top performers and more Olympic cycles. In addition to this, including different variables such as training methods, injury records, and technological changes could possibly make clearer what is contributing to performance trends we are seeing between different genders and age groups.

References

[1] Allen, S. V., & Hopkins, W. G. (2015). Age of Peak Competitive Performance of Elite Athletes: A Systematic Review. Sports Medicine, 45(10), 1431–1441. https://doi.org/10.1007/s40279-015-0354-3

[2] Pyne, D., Trewin, C., & Hopkins, W. (2004). Progression and variability of competitive performance of Olympic swimmers. Journal of Sports Sciences, 22(7), 613–620. https://doi.org/10.1080/02640410310001655822

[3] König, S., Valeri, F., Wild, S., Rosemann, T., Rüst, C. A., & Knechtle, B. (2014). Change of the age and performance of swimmers across World Championships and Olympic Games finals from 1992 to 2013 – a cross-sectional data analysis. SpringerPlus, 3(1). https://doi.org/10.1186/2193-1801-3-652

[4] Silva, J. K. F. da, Enes, A. A. N., Sotomaior, B. B., Barbosa, M. A. R., Souza, R. O. de, & Osiecki, R. (2020). Analysis of the performance of finalist swimming athletes in Olympic games: Reaction time, partial time, speed, and final time. Journal of Physical Education and Sport, 20(2), 627–633. https://doi.org/10.7752/jpes.2020.02080

[5] Patoz A, Finiel L and Borrani F (2024), 2024: anticipating record-breaking performances in front crawl swimming through mathematical analysis. Front. Physiol. 15:1397946. doi: 10.3389/fphys.2024.1397946

[6] Berthelot, G., Len, S., Hellard, P., Tafflet, M., Guillaume, M., Vollmer, J., Gager, B., Quinquis, L., Marc, A., & Toussaint, J. (2011). Exponential growth combined with exponential decline explains lifetime performance evolution in individual and human species. AGE, 34(4), 1001–1009. https://doi.org/10.1007/s11357-011-9274-9

[7] Mazzilli, F. M. (2016). Increase in the age of Olympic swimmers in modern times. The Journal of Strength and Conditioning Research, 31(8), 2208–2215. https://doi.org/10.1519/jsc.0000000000001693

[8] Elmenshawy, A. R., Machin, D. R., & Tanaka, H. (2015). A rise in peak performance age in female athletes. Age (Dordrecht, Netherlands), 37(3), 9795. https://doi.org/10.1007/s11357-015-9795-8

[9] Chatterjee, S., & Laudato, M. (1996). An analysis of world record times of men and women in running, skating, and swimming. Journal of strength and conditioning research, 10(4), S. 274-278.

[10] Stanula, A., Maszczyk, A., Roczniok, R., Pietraszewski, P., Ostrowski, A., Zając, A., & Strzała, M. (2012). The development and prediction of athletic performance in freestyle swimming. Journal of human kinetics, 32, 97–107. https://doi.org/10.2478/v10078-012-0027-3

[11] Mujika, I. (2013). The alphabet of sport science research starts with Q. International Journal of Sports Physiology and Performance, 8(5), 465–466. https://doi.org/10.1123/ijspp.8.5.465

[12] Schulz, R., & Curnow, C. (1988). Peak performance and age among superathletes: track and field, swimming, baseball, tennis, and golf. Journal of Gerontology, 43(5), P113–P120. https://doi.org/10.1093/geronj/43.5.p113