Competition age: does it matter for swimmers?

Dennis-Peter Born1,2*, Ina Stäcker2, Michael Romann2 and Thomas Stöggl3,4

Abstract

Objective: To establish reference data on required competition age regarding performance levels for both sexes, all swimming strokes, and race distances and to determine the effect of competition age on swimming performance in the context of other common age metrics. In total, 36,687,573 race times of 588,938 swimmers (age 14.2 ± 6.3 years) were analyzed. FINA (Fédération Internationale de Natation) points were calculated to compare race times between swimming strokes and race distances. The sum of all years of race participation determined competition age.

Results: Across all events, swimmers reach top-elite level, i.e. > 900 FINA points, after approximately 8 years of competition participation. Multiple-linear regression analysis explained up to 40% of variance in the performance level and competition age showed a stable effect on all race distances for both sexes ($\beta$ = 0.19 to 0.33). Increased race distance from 50 to 1500 m, decreased effects of chronological age ($\beta$ = 0.48 to −0.13) and increased relative age effects ($\beta$ = 0.02 to 0.11). Reference data from the present study should be used to establish guidelines and set realistic goals for years of competition participation required to reach certain performance levels. Future studies need to analyze effects of transitions between various swimming strokes and race distances on peak performance.

Keywords: Elite, Long-term athlete development, Reference data, Relative age, Swimming, Talent

Introduction

At international competitions, i.e. European championships, chronological age was related to success [1], possibly due to accumulated training time and competition experience, i.e. deliberate practice, contributing to the achievement of top-elite performance [2, 3]. As internationally successful swimmers reach peak performance between 21 and 26 years of age and peak performance duration is limited (2.6 ± 1.5 years) [4], swimmers may have to start early to reach top-elite performance on time and not to miss their window of opportunity.

While the concept of deliberate practice [2, 3] is hardly discussed among experts in the field, it may not apply to all sports to the same extent [5–7]. In some sports, athletes may require far less than the proposed 10 years of deliberate practice [2, 3] to achieve international success [7]. However, swimming is a highly technical sport that requires athletes to perform in a very specific and for mankind unusual environment. As water reduces movement efficiency compared to on-land locomotion [8], more practice in the specific environment may be required for top-elite success in swimming. Additionally, endurance sports, such as swimming, require a high aerobic capacity and benefit from accumulated hours of training over multiple years [9]. Therefore, the concept of deliberate practice may be more important in swimming compared to other sports and competition age may heavily contribute to elite-age success.

Additionally, the relative age, i.e. age-related difference between athletes born early and late in the year, affects talent selection and progression towards top-elite performance [10, 11]. By the age of 8 years, early compared to late in the year born individuals have a physical...
advantage of 10% [10]. Therefore, by the age of 13, twice the number of Australian national level swimmers were born early in the year [11]. The RAE was larger in male compared to female swimmers [12, 13] and most pronounced in short-distance events, butterfly (BU), and breaststroke (BR) [12]. The RAE was most evident in the younger age-categories and reversed towards senior age [12]. Therefore, the main aim of the study was to determine the effect of competition age, i.e. accumulated years of competition participation, on swimming performance in the context of the other common age metrics, i.e. relative and chronological age. Additionally, reference data were established for competition age required to reach various performance levels across both sexes, all swimming strokes, and all race distances.

Main text
Materials and methods
Subjects
In total, 36,687,573 race times of 588,938 swimmers (males: 15.9 ± 5.8 and females: 14.7 ± 4.7 years of age) from the years 2000 until 2019 were included in the present study. Data were provided from the official database [14] of the European Swimming Federation LEN (Ligue Européenne de Natation) with permission for anonymized publication of the results. The study was approved by the lead institution’s internal review board for ethical affairs (Reg.-Nr. 139_LSP_V01) and is in accordance with the latest version of the code of conduct of the World Medical Association for studies involving human subjects (WMA Declaration of Helsinki). No consent for participation was required as anonymized race results were provided from a publicly available database and analyzed ex post facto.

Data analysis
To compare race times between swimming strokes and race distances, FINA (Fédération Internationale de Natation) points for each race time were calculated [15]. FINA points are the official method of the International Swimming Association to relate race times to the current world record, i.e. 1000 points.

\[
\text{FINA points [a.u.]} = 1000 \times \left(\frac{\text{World record}}{\text{Race time}}\right)^3
\]

Analysis step 01 From the 2019 race data, each individual swimmer’s best race, i.e. most FINA points, was used to establish the ranking for each race category. As race categories were defined: (a) all events including all swimming strokes and all race distances from 50 to 1500 m; (b) each swimming stroke, i.e. BU, backstroke (BA), BR, freestyle (FR), individual medley (IM), using pooled data of its 50, 100, and 200 m races; (c) each race distance using the 50, 100, 200, 400, 800, and 1500 m FR events. The rankings were established based on long-course races, due to their superior recognition, i.e. at the Olympics, compared to short-course events (25 m pool length).

Analysis step 02 Within each race category, each swimmer was tracked retrospectively, and the races extracted for every year from 2000 to 2019. Total number of years with race times of the particular race category determined competition age. As short-course races contribute to the training and development process, short- and long-course races were included for determination of competition age (Additional file 1: Fig. S1). The analysis was performed for male and female swimmers individually. Data processing was performed with Python [16] using the ‘pandas’ library [17] and Microsoft Excel (Excel 2016, Microsoft Corporation, Redmond, WA, USA).

Statistical analysis
Participants aged beyond the mean ± three standard deviations of the race category were removed as outliers [18]. Normality was investigated with standardized residuals showing a random pattern across predicted values in the scatter plot, a Gaussian distribution in the histogram, and a straight diagonal line in the Q-Q plot [18]. Multiple linear regression analysis was used to assess the effect of competition age [years] in the context of the other common age metrics, i.e. relative [month of birth] and chronological age [years]. Swimming performance, i.e. FINA points, were used as dependent variable. Collinearity was controlled with a tolerance > 0.10 and a variance inflation factor < 10 [18]. An alpha-level < 0.05 indicated a significant effect. The statistical analysis was performed using JASP statistical software package version 0.14 (JASP-Team, University of Amsterdam, Amsterdam, The Netherlands).

Results
Across all events, swimmers that reached a performance level of > 900 FINA points accumulated approximately 8 years of competition practice (males 7.7 ± 4.2 years and females 8.0 ± 3.2 years). Table 1 shows the descriptive analysis of competition age for different levels of swimming performance.

Regression analysis explained up to 40% of variance in swimming performance, i.e. FINA points, and showed a significant effect of competition age, chronological age, and relative age \((P < 0.001)\). Regarding race distances, there was a stable effect of competition age from 50 to 1500 m in males \((\beta = 0.21 \text{ to } 0.33, \text{ Table 2})\) and females \((\beta = 0.19 \text{ to } 0.33, \text{ Table 3})\). However, the effect of chronological age decreased the longer the race distance in males \((\beta = 0.48 \text{ to } -0.12)\) and females \((\beta = 0.39 \text{ to } -0.21)\).
to \(-0.13\). The effect of relative age was fairly small yet increased with race distance from 50 to 1500 m in males ($\beta = 0.02$ to 0.11) and females ($\beta = 0.03$ to 0.08).

**Discussion**

Swimmers accumulated approximately 8 years of competition practice to reach top-elite level, i.e. > 900 FINA points, regardless of event. The present descriptive data show years of competition practice needed to reach various performance levels for each swimming stroke and race distance. While the regression model explained up to 40% of variance in swimming performance depending on the event, the effect of competition age remained stable across all race distances. The effect of chronological age continuously decreased, and the effect of relative age continuously increased the longer the race distance, i.e. from 50 to 1500 m.

Previous studies showed the largest relative age effect at early junior age that decreased the older the swimmers [10] and even reversed towards senior age [12]. As the present study analyzed swimming performance up to elite age, the before mentioned aspect is one explanation as to why the relative age effect was comparatively smaller in the regression model than the other age metrics. With a particular interest on the RAE and potential differences between swimming strokes and sexes [12,
studies should focus on the young age groups from which the RAE originates [10, 11]. Previous studies found the largest RAE in short-distance swimming events [12]. With the large age-range analyzed here and age of peak performance being lowest in the longer swimming events [4], the present study showed an opposite trend towards an increasing RAE the longer the race distance. In conclusion, coaches and federation officials should be aware of the relative age effect. Early deselection of young swimmers with a late birthday in the year results in an irreversible loss of talents [11].

The present study showed a stable effect of competition age for all swimming events, which supports previous findings that top-elite performance needs to be developed over time and requires accumulated years of practice [2, 3]. However, as swimmers usually

| Regression model | Regression coefficients |
|------------------|-------------------------|
|                  | n  | R²  | F    | p   | Comp. age | Relative age | Chronol. age | Comp. age | Relative age | Chronol. age | Comp. age | Relative age | Chronol. age | Comp. age | Relative age | Chronol. age | Comp. age | Relative age | Chronol. age | Comp. age | Relative age | Chronol. age | Comp. age | Relative age | Chronol. age |
| All events       | 39,487 | 0.25 | $F(3|39483) = 4326$ | <0.001 | 0.34 | 24.6 | 74 | <0.001 |
| Butterfly        | 42,926 | 0.29 | $F(3|42922) = 5897$ | <0.001 | 0.24 | 7.0 | 52 | <0.001 |
| Backstroke       | 23,603 | 0.36 | $F(3|23600) = 4400$ | <0.001 | 0.24 | 14.3 | 54 | <0.001 |
| Breaststroke     | 22,258 | 0.34 | $F(3|22254) = 3878$ | <0.001 | 0.24 | 15.5 | 39 | <0.001 |
| Freestyle        | 34,759 | 0.32 | $F(3|34755) = 5502$ | <0.001 | 0.06 | 2.5 | 11 | <0.001 |
| Individual medley| 16,070 | 0.33 | $F(3|16066) = 2635$ | <0.001 | 0.14 | 7.7 | 18 | <0.001 |
| 50 m Freestyle   | 52,043 | 0.30 | $F(3|52039) = 7304$ | <0.001 | 0.32 | 8.1 | 82 | <0.001 |
| 100 m Freestyle  | 28,309 | 0.40 | $F(3|28305) = 6390$ | <0.001 | 0.24 | 15.6 | 45 | <0.001 |
| 200 m Freestyle  | 20,225 | 0.33 | $F(3|20221) = 3279$ | <0.001 | 0.02 | 0.9 | 4 | <0.001 |
| 400 m Freestyle  | 14,005 | 0.11 | $F(3|14001) = 570$ | <0.001 | 0.11 | 13.3 | 14 | <0.001 |
| 800 m Freestyle  | 7695  | 0.07 | $F(3|7691) = 195$ | <0.001 | 0.23 | 11.8 | 20 | <0.001 |
| 1500 m Freestyle | 5466  | 0.07 | $F(3|5462) = 130$ | <0.001 | 0.11 | 4.8 | 9 | <0.001 |
enter competitive swimming aged 8–10 years, and age of peak performance is 21–26 years [4], the average 8 years of accumulated competition practice necessary to reach top-elite performance (> 900 FINA points) still allow enough time for solid and progressive talent development. This is particularly important to lay the foundation for progression in the flat part of the performance curve towards elite age [19], when swimmers reach a performance level of > 900 FINA points. In this regard, talent programs benefit from a less hasty performance progression, a less harsh selection process, and increased focus on long-term performance development rather than short-term success during adolescence [20–22]. As ‘lack of enjoyment’ and ‘getting bored’ are two major factors for drop-out from swimming [23], particular attention should be placed

| Regression model          | Regression coefficients | n   | R² | F       | p      | Comp. age | b_i | t_i | p     |
|---------------------------|-------------------------|-----|----|---------|--------|-----------|-----|-----|-------|
| All events                |                         | 39,572 | 0.20 | 3361 | < 0.001 | 0.34 | 22.9 | 71  | < 0.001 |
| Butterfly                 |                         | 26,925 | 0.28 | 3436 | < 0.001 | 0.21 | 12.2 | 35  | < 0.001 |
| Backstroke                |                         | 26,136 | 0.28 | 3456 | < 0.001 | 0.25 | 15.9 | 42  | < 0.001 |
| Breaststroke              |                         | 23,676 | 0.26 | 2754 | < 0.001 | 0.31 | 10.8 | 50  | < 0.001 |
| Freestyle                 |                         | 36,037 | 0.26 | 4184 | < 0.001 | 0.32 | 20.3 | 64  | < 0.001 |
| Individual medley         |                         | 18,263 | 0.25 | 2070 | < 0.001 | 0.30 | 10.2 | 56  | < 0.001 |
| 50 m Freestyle            |                         | 31,906 | 0.29 | 4319 | < 0.001 | 0.24 | 14.2 | 42  | < 0.001 |
| 100 m Freestyle           |                         | 29,808 | 0.32 | 4583 | < 0.001 | 0.39 | 16.6 | 69  | < 0.001 |
| 200 m Freestyle           |                         | 21,365 | 0.26 | 2431 | < 0.001 | 0.37 | 16.1 | 53  | < 0.001 |
| 400 m Freestyle           |                         | 14,646 | 0.11 | 595  | < 0.001 | 0.26 | 14.4 | 32  | < 0.001 |
| 800 m Freestyle           |                         | 8104  | 0.07 | 215  | < 0.001 | 0.25 | 12.4 | 22  | < 0.001 |
| 1500 m Freestyle          |                         | 5654  | 0.05 | 89   | < 0.001 | 0.19 | 8.8  | 14  | < 0.001 |

Table 3: Multiple linear regression analysis of swimming performance, i.e. FINA points, as dependent variable and competition (comp.) age [years], relative age [month of birth], and chronological (chronol.) age [years] as predictors with standardized (beta_i) and unstandardized (b_i) regression coefficients in female swimmers.
on keeping swimmers in the system and motivated for training and competition [24].

Previous studies show the value of deliberate play which is the unspecific and unstructured involvement in the same or other sports [25, 26]. Compared to their national counterparts, world class athletes are in general more involved in other sports [6]. Due to the specific characteristics of water [8], swimmers may have to accumulate a larger volume of training and competition in their sport-specific environment compared to other sports. Thus, other aquatic sports, such as water polo, underwater rugby, or competitive aquatic lifesaving, may contribute to the development of water feeling, swimming technique, aerobic, and anaerobic endurance, while maintaining a high level of enjoyment [27, 28]. Additionally, recent studies showed the importance of start and turn performances for modern swim races [29, 30]. The push-off from a solid base, i.e. starting block and pool wall, requires high leg strength and power [31, 32]. Therefore, swimmers could also benefit from on-land activities and weight-bearing sports more than traditionally expected. From a practical perspective, coaches and federation officials should be aware of the concept of deliberate play [25, 26]. Promoting other aquatic and on-land sports during adolescence helps to maximize volume of practice, while sustaining enjoyment and motivation to keep young swimmers in the system rather than losing them to other endurance or explosive sports [23].

Conclusion
The stable effect of competition age across all swimming events shown in the present study supports the findings that accumulated practice contributes to elite age success [2, 3], in particular in highly technical endurance sports, such as swimming. The approximately 8 years of accumulated competition practice required to reach top-elite performance (> 900 FINA points) still allows enough time to build a solid foundation with broad and variable skill acquisition before reaching peak performance age. Reference data from the present study should be used to establish guidelines and set realistic goals for years of competition practice required to reach various performance levels.

Limitations
The present study determined competition age, assuming that regular competition participation is part of a well-structured training process. However, future studies should use questionnaires and training diaries to determine training age. FINA point ranking was established based on each swimmer’s best race within the race category. As swimmers specialize in a particular swimming stroke rather than race distance [33], the swimming strokes were compared using pooled data of the 50, 100, and 200 m events. Therefore, transitions between race distances were not accounted for. As 800 m (for males) and 1500 m (for females) were added to the 2021 Olympic program [34], long-distance swimmers may have started to compete in both events with high success rates despite low competition age in one of the events. Future studies should pay particular attention to transitions and cross effects between swimming strokes and race distances. Additionally, for top-elite swimmers, there may be a non-linear relationship between years of practice and performance level. After an initial steep incline, the curve would be expected to plateau and increased number of years in competition would not further translate into improved swimming performance. With the large sample size analyzed in the present study including swimmers from various performance levels down to < 100 FINA points, such relationship was not found. Future studies should investigate individual career pathways and competition history towards top-elite success based on longitudinal tracking.
Competing interests
The authors have no competing interest.

Author details
1 Swiss Swimming Federation, Section for High-Performance Sports, Bern, Switzerland. 2 Department of Elite Sport, Swiss Federal Institute of Sport Magglingen, Hauptstrasse 247, 2532 Magglingen, Switzerland. 3 Department of Sport and Exercise Science, University of Salzburg, Salzburg, Austria. 4 Red Bull Athlete Performance Center, Salzburg, Austria.

Received: 18 November 2021  Accepted: 10 February 2022
Published online: 23 February 2022

References
1. Born DP, Lomaix I, Horvath S, Meisser E, Seidenschwarz P, Burkhardt D, Romann M. Competition-based success factors during the talent pathway of elite male swimmers. Front Sports Active Living. 2020;2:589938.
2. Ericsson KA, Harwell KW. Deliberate practice and proposed limits on the effects of practice on the acquisition of expert performance: why the original definition matters and recommendations for future research. Front Psychol. 2019;10:2396.
3. Ericsson KA, Krampe RT, Tesch-Romer C. The role of deliberate practice in the acquisition of expert performance. Psychol Rev. 1993;100:363–406.
4. Allen SV, Vandenbogaerde TJ, Hopkins WG. Career performance trajectories of Olympic swimmers: benchmarks for talent development. Eur J Sport Sci. 2014;14:643–51.
5. Tucker R, Collins M. What makes champions? A review of the relative contribution of genes and training to sporting success. Br J Sports Med. 2012;46:555–61.
6. Gullich A, Emrich E. Considering long-term sustainability in the development of world class swimmers. Eur J Sport Sci. 2014;14(1Suppl 1):S383–397.
7. Gullich A. Many roads lead to Rome—developmental paths to Olympic gold in men’s field hockey. Eur J Sport Sci. 2014;14:763–71.
8. Zampaö P, Cortesi M, Gatta G. The energy cost of swimming and its determinants. Eur J Appl Physiol. 2020;120:41–66.
9. Allen SV, Hopkins WG. Age of peak competitive performance of elite athletes: a systematic review. Sports Med. 2015;45:1431–41.
10. Romann M, Cobley S. Relative age effects in athletic sprinting and corrective adjustments as a solution for their removal. PLoS ONE. 2015;10:e0122988.
11. Cobley S, Abbott S, Dogramaci S, Kable A, Saltier J, Hinttermann M, Romann M. Transient relative age effects across annual age groups in national level Australian swimming. J Sci Med Sport. 2018;21:839–45.
12. Lorenzo-Calvo J, de la Rubia A, Mon-Lopez D, Hontoria-Galan M, Marquina M, Veiga S. Prevalence and impact of the relative age effect on competition performance in swimming: a systematic review. Int J Environ Res Public Health. 2021;18(20):10561.
13. Costa AM, Marques MC, Louro H, Ferreira SS, Marinho DA. The relative age effect among elite youth competitive swimmers. Eur J Sport Sci. 2013;13:437–44.
14. Swimrankings.net. https://www.swinrankings.net/index.php&language=en. Accessed 10 Sep 2021.
15. Fédération Internationale de Natation (FINA). Swimming points. https://www.fina.org/swimming/points. Accessed 15 Sep 2021.
16. Python 3. https://www.python.org/. Accessed 12 Sept 2021.
17. Pandas. Data Analysis and Manipulation Tool for Python (version 1.1.4) https://pandas.pydata.org/. Accessed 12 Sep 2021.
18. Field A. Discovering statistics using IBM SPSS Statistics. Los Angeles: Sage Publications Ltd, 2013.
19. Alshodhik K, Petersen C, Clarke J. Improvement and variability of adolescent backstroke swimming performance by age. Front Sports Act Living. 2020;2:46.
20. Rees T, Hardy L, Gullich A, Abernethy B, Cote J, Woodman T, Montgomery H, Laing S, Ward C. The great British medalists project: a review of current knowledge on the development of the world’s best sporting talent. Sports Med. 2016;46:1041–58.
21. Brustio PR, Cardinale M, Lupo C, Varalda M, De Pasquale P, Boccia G. Being a top swimmer during the early career is not a prerequisite for success: a study on sprinter strokes. J Sci Med Sport. 2021;24(12):1272–7
22. Moesch K, Elbe AM, Hauge ML, Wikman JM. Late specialization: the key to success in centimeters, grams, or seconds (cgs) sports. Scand J Med Sci Sports. 2011;21:282–290.
23. Montero D, Cad L, Marinho DA, Moutao J, Vitorino A, Bento T. Determinants and reasons for dropout in swimming—systematic review. Sports. 2017;5:50.
24. Barreiros A, Cote J, Fonseca AM. From early to adult sport success: analysing athletes’ progression in national squads. Eur J Sport Sci. 2014;14(4Suppl1):S178–182.
25. Côté J, Lidor R, Hackfort D. ISSP position stand: to sample or to specialize? Seven postulates about youth sport activities that lead to continued participation and elite performance. Int J Sport Exerc Psychol. 2009;7:7–17.
26. Gullich A, Fass L, Gies C, Wald V. On the empirical substantiation of the definition of “Deliberate Practice” (Ericsson et al. 1993) and “Deliberate Play” (Côté et al. 2007) in Youth Athletes. J Expertise. 2020;3:1–19.
27. Reichmuth D, Olstad BH, Born DP. Key performance indicators related to strength, endurance, flexibility, anthropometrics, and swimming performance for competitive aquatic lifesaving. Int J Environ Res Public Health. 2021;18:3454.
28. Smith HK. Applied physiology of water polo. Sports Med. 1998;26:317–34.
29. Born DP, Kugler J, Polach M, Romann M. Start and turn performances of elite male swimmers: benchmarks and underlying mechanisms. Sports Biomech. 2021. https://doi.org/10.1080/14763141.2021.1872693.
30. Polach M, Thiel D, Kenik J, Born DP. Swimming turn performance: the distinguishing factor in 1500 m world championship freestyle races? BMC Res Notes. 2021;14:24:28.
31. Born DP, Stoggl T, Petrov A, Burkhardt D, Luthy F, Romann M. Analysis of freestyle swimming sprint start performance after maximal strength or vertical jump training in competitive female and male junior swimmers. J Strength Cond Res. 2020;34:323–31.
32. Nicol E, Ball K, Tor E. The biomechanics of freestyle and butterfly turn technique in elite swimmers. Sports Biomech. 2021;20:444–57.
33. Stewart AM, Hopkins WG. Consistency of swimming performance within and between competitions. Med Sci Sports Exerc. 2000;32:997–1001.
34. International Olympic Committee (IOC). Swimming events Tokyo 2021. https://olympics.com/tokyo-2020/olympic-schedule-and-results.html. Accessed 19 Oct 2021.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.