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Research article

From Entry to Finals: Progression and Variability of Swimming Performance at the 2022 FINA World Championships

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Abstract
The aim of the present study was two-fold: (i) to analyze the progression and variability of swimming performance (from entry times to best performances) in the 50, 100, and 200 m at the most recent FINA World Championships and (ii) to compare the performance of the Top16, semifinalists, and finalists between all rounds. Swimmers who qualified with the FINA A and B standards for the Budapest 2022 World Championships were considered. A total of 1102 individual performances swimmers were analyzed in freestyle, backstroke, breaststroke, and butterfly events. The data was retrieved from the official open-access websites of OMEGA and FINA. Wilcoxon test was used to compare swimmers' entry times and best performances. Repeated measures ANOVA followed by the Bonferroni post-hoc test were performed to analyze the round-to-round progression. The percentage of improvement and variation in the swimmers' performance was computed between rounds. A negative progression (entry times better than best performance) and a high variability (> 0.69%) were found for most events. The finalists showed a positive progression with a greater improvement (~1%) from the heats to the semifinals. However, the performance progression remained unchanged between the semifinals and finals. The variability tended to decrease between rounds making each round more homogeneous. Coaches and swimmers can use these indicators to prepare a race strategy between rounds.

Key words: Swimming, swimmers, analysis, race, competition.

Introduction

Participation in a World Championship is one of the most important achievements in an athlete's career. While for some it means a moment of experience and enjoyment at the event, for others it can be an opportunity to improve their personal record or to increase their curriculum with presence in the finals and even winning medals. The 2022 FINA World Aquatics Championships held in Budapest brought together more than 2000 participants from 180 countries. To qualify for such a demanding competition, swimmers usually cover a wide spectrum of competitions within a year (Born et al., 2020). Most training plans are designed to excel in a single competition or a group of competitions (Mujika et al., 2002). This means that some swimmers only need one attempt to swim within or below the qualifying times, while others require a greater number of attempts. Due to the greater effort in chasing qualification, several swimmers end up struggling more than others to progress in the major event (Pyne et al., 2004).

Progression and variability of swimming performance to and within the major competitions have been topics of interest and debate over the years, with a ~1% performance improvement within the year being necessary to be part of a major event (Pyne et al., 2004). It is also understandable that, within the major event, each swimmer needs to show fairly improvements from the heats to the semifinals and then to the finals. In the last 2021 European Swimming Championships, the 100 and 200 m competitors were able to improve their performance from round to round (Cuenca-Fernandez et al., 2021), a common and expected trend for most swimmers. However, some of the fastest swimmers do not perform at their best in the first rounds of the event mainly to spare energy (Mohamed et al., 2021), which can lead to different performance profiles based on the swimmers' rank.

In World-Class swimming competitions, most of these performance progressions are analyzed between rounds, ruling out entry times. Entry times are currently one of the most important indicators that coaches and swimmers pay attention. It is a way to know the ability of their opponents and, if necessary, adjust competition strategies. Moreover, the way in which a competition will unfold (i.e., faster or slower rounds and the percentage of improvement between rounds) might be determined by the entry times. Surprisingly, only a single study determined the overall progression of performance in a swim competition taking entry times as a starting point, with swimmers from the 2004 Athens Olympics having a 0.58% performance decline compared to their entry times in 68% of swimming events (Issurin et al., 2008). Thus, there is a research gap on whether major competitions are still a place to excel if entry times are considered as the starting point for performance progression analysis. This is even more important when the last World Swimming Championships took place just under a year after the Olympic Games, not so common considering a traditional season calendar.

Recently some FINA rules have been changed and new strategies have been developed to support teams and swimmers (Barbosa et al., 2021), as it is important to better understand the characteristics of World Class competition these days. For government bodies it is also important to understand how the changes in the competitive calendar will affect the competition characteristics. As the number of events per edition of the World Championships has steadily grown over the years, it is important to investigate

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the progression of male and female swimmers for each round and event. Regarding the 2022 World Swimming Championships, the present study aimed to: (i) analyze the progression of men's and women's (FINA A and B qualifying standards) swimming (race time), performance improvement (%IMP), and variability (%CV) between entry times and the best performances in the 50, 100, and 200 m for all competitive swimming techniques; and (ii) analyze specifically the entry times and all rounds, i.e., entry-heats, heats-semifinals, and semifinals-finals in men and women Top16, semifinalists, and finalists. It was hypothesized that the best performances achieved in all rounds would be below the entry times (evidencing a negative %IMP) and the finalists would demonstrate a higher and positive %IMP (mainly between heats and semifinals) than their remaining counterparts.

Methods

Participants

Swimmers qualified for the long-course 19th FINA World Championships (2022, Budapest, Hungary) in the 50, 100 and 200 m freestyle (Fr), backstroke (Bk), breaststroke (Br), and butterfly (Fly) events were analyzed. Entry times according to the FINA A and B qualification standards achieved between March 1, 2020 and May 15, 2022 were considered as inclusion criteria. Swimmers who entered without qualifying time, did not start (DNS) the event, or were disqualified were excluded. A total of 1102 individual performances (629 for men and 473 for women) were included for further analysis.

Design and procedures

An observational retrospective design was selected for the present study. Swimmers demographics and official race times were retrieved from the official open-access websites (https://www.omegatiming.com and www.fina.org). Data were downloaded and independently verified by two researchers for possible missing cases. Event, swimmers' name, date of birth, entry times, official race times in the heats, semi-finals and finals, and best performances (independently of the round the swimmer reached) were extracted. Data were collected from all swimmers who participated in the 50, 100, and 200 m Fr, Bk, Br, and Fly events. The Top16 (sixteen swimmers), semi-finalists (eight swimmers), and finalists (eight swimmers) were considered for each event. In addition, all race times have been converted from min to s if applicable to the event. The Institutional Ethics Committee of the host University stated that ethics approval was not required for this type of study design.

Statistical analysis

Shapiro-Wilk and Levene's tests were used to assess the normality and homoscedasticity (respectively). Non-parametric statistics were used if the normality assumption was violated. The mean plus one standard deviation (Mean±SD) was computed as descriptive statistics and the dataset was divided according to the swimmers' sex. The Wilcoxon signed-rank test was used to compare entry times and best performances. In addition, effect size (ES) was calculated as previously proposed (Fritz et al., 2012) and interpreted based on Cohen's guidelines (Coolican, 2009): small (0.20), moderate (0.30), and large (0.50). Repeated-measures ANOVA followed by the Bonferroni post-hoc test were performed to analyze the variation between rounds of the Top16, semifinalists and finalists in the entry-heats, heats-semifinals, and semifinals-finals pairs. The ANOVA assumptions were tested and a Greenhouse-Geisser correction was considered if the sphericity assumption was violated.

Partial Eta Squared (η_p^2) was calculated as an ES and interpreted according to Ferguson (2009): no effect ($\leq$ 0.04), minimum effect (0.04-0.25), moderate effect (0.25-0.64), and strong effect (> 0.64). The percentage performance improvement (%IMP) between rounds was calculated as previously proposed (Costa et al., 2010) with negative/positive values evidencing a decrease/increase in performance (i.e., race time increase/decrease, respectively). The variation of the swimmers' performance between rounds (within-swimmer variation) or the intra-swimmer's CV was computed and transformed into percentage (%CV, Equation 1) according to Hopkins et al. (1999).

$$\%CV = \frac{\text{SD (e.g., Entry and Heats)}}{\text{Mean (e.g., Entry and Heats)}}\ x\ 100 \quad \text{(Equation 1)}$$

All statistical analysis was performed in the SPSS software (v.27, IBM, SPSS Inc., Chicago, IL, USA) with a statistical significance set at $p \leq 0.05$.

Results

The descriptive analysis of the swimmers' entry times and best performances across the 2022 World Championships is shown in Table 1. Differences were found in most of the events with a moderate to large effect, except in Bk50 and Fly50 for both sexes, and in Fr200 for women. The greatest performance decrease in men was found in the 200 m distance in Bk and Br (> 1%), while the Fr100 and Bk50 showed the lowest values (~0.30%). Regarding women, the Bk100 and 200, and Br100 and 200 showed a > 1% performance decrease, whereas the Fr200, Bk50 and Fly200 showed the lowest values (-0.21, -0.34 and -0.34%, respectively). The intra-swimmer's CV ranged between 0.75-1.14% in men and between 0.69-1.16% in women.

Tables 2 and 3 represent the round effect in the men´s Top16, semi-finalists and finalists, with differences with moderate to strong effect being found in most events for all groups. However, no differences were found in Br50 and Fly50 for all groups, Fr100, Br100 and Fly200 for semi-finalists, and Bk50 for the finalists. The men's round-to-round analysis evidenced that most of the entry-heats performances decreased for the Top 16 and semi-finalists, and in the heats-semifinals round increases were mainly found for the finalists group. All 50 m performances remained unchanged between heats-semifinals for semi-finalists and finalists, but higher %IMP and %CV (except for Br50) were found for finalists. A positive %IMP was observed between heats and semifinals in most events and %CV presented a tendency to be lower in the semi-finalists than in the finalists. Furthermore, a decrease between semifinals-finals was only shown in Fr100. The %IMP between semifinals-finals presented mixed results, i.e., negative or positive performance improvements according to each event. In addition, a tendency to find a decrease in %CV between rounds (from E to F) was verified for the cohort of finalist swimmers.

Tables 4 and 5 report the round effect on the women's Top 16, semi-finalists and finalists, with most events showing differences with minimum to strong effect for all swimmer groups. No differences were found in Br50 for all groups and in Bk50, Fly50, Fr100, Fly100, and Fr200 for the semi-finalists. Round-to-round analysis for women revealed performance decreases between entry and heats in most events. The Bk50, Fly50, Br100, and Fly200 showed no differences for finalists. A negative %IMP, i.e., performance decreases in the heats with a higher %CV (> 0.67%) were observed in most events for all groups. When comparing heats and semifinals, performance improvements were found mainly for the finalist group, whose swimmers showed a tendency to obtain a higher %IMP than the semi-finalists (despite the %IMP being positive for both). The comparison of semifinals and finals did not reveal differences in all events. The %IMP presented mixed results, i.e., a negative or positive performance variation, according to the event and the %CV showed a downward trend in all rounds (from entry to finals) in the finalists group.

Discussion

This study aimed to analyze the progression and variability of swimming performance in the 50, 100, and 200 m events and compare the performance of the Top16, semi-finalists and finalists among all rounds of the Budapest 2022 Championship. A negative progression and high variability (> 0.69%) were found for most of the analyzed events, as the best performances achieved within the competition were worse when compared with the entry times. According to our hypothesis, the finalists presented a greater (positive) improvement from the heats to the semifinals, but the performance remained unchanged between the semifinals and the finals. The variability tended to decrease between rounds for female and male swimmers, making each round more homogeneous and competitive (as expected).

The progression of swimming performance analysis within and between competitive seasons has been used primarily for training purposes (Barbosa et al., 2021), particularly to adjust training load and allow swimmers to reach qualifying times/places for important competitions. When assessed a single competition, i.e., monitoring the performance progression between rounds, it serves primarily for race adjustments (Mauger et al., 2012). In this context, the entry times play an important role, being seen as the starting point for comparing competitors. In addition, it can be an effective approach to understanding the general level of competition when it ends, for example by looking at whether it was an event that triggered better personal performances. For instance, swimmers who participated in the 2004 Athens Olympics presented a decrease in swimming performance in relation to their entry times (Issurin et al., 2008). However, it remains unclear how entry times can define the course of a competition, particularly right after the Olympics.

Table 1. Entry times and the best performance values across the 2022 World Championships in men and women swimming events.

	Event	Distance (m)	Entry (s)	Best performance (s)	p-value	ES	%IMP	%CV
Men	Freestyle	50 (n=78)	23.12±1.75	23.29±1.67	<0.001	0.43	-0.72±1.65	1.06
		100 (n=86)	50.81±3.05	50.97±2.99	0.045	0.22	-0.31±1.47	0.75
		200 (n=55)	109.36±5.24	109.95±4.72	0.002	0.43	-0.54±1.31	0.80
	Back-stroke	50 (n=40)	25.58±1.33	25.66±1.27	0.166	0.22	-0.33±1.77	0.98
		100 (n=38)	54.23±1.73	54.67±1.79	0.004	0.46	-0.79±1.15	1.02
		200 (n=30)	118.62±3.33	119.88±3.63	0.001	0.61	-1.03±1.47	0.96
	Breast-stroke	50 (n=51)	28.31±1.96	28.56±2.08	0.002	0.42	-0.82±1.65	1.05
		100 (n=57)	61.64±2.59	62.23±2.55	<0.001	0.58	-0.93±1.60	0.93
		200 (n=39)	132.44±5.34	134.13±5.30	<0.001	0.65	-1.25±1.62	1.14
	Butterfly	50 (n=60)	24.32±1.62	24.32±1.64	0.553	0.08	0.02±1.54	0.80
		100 (n=57)	53.36±3.45	53.76±3.04	<0.001	0.58	-0.76±1.73	0.94
		200 (n=38)	116.85±2.74	117.85±3.37	0.004	0.47	-0.83±1.50	0.96
Women	Freestyle	50 (n=67)	26.90±3.23	27.12±2.95	<0.001	0.52	-0.86±1.89	1.15
		100 (n=49)	57.72±5.57	58.08±5.68	0.001	0.47	-0.60±1.12	0.72
		200 (n=37)	121.93±7.99	122.16±7.20	0.409	0.14	-0.21±1.33	0.69
	Back-stroke	50 (n=32)	28.77±1.60	28.87±1.64	0.210	0.22	-0.34±1.39	0.72
		100 (n=39)	61.80±3.42	62.52±3.60	<0.001	0.73	-1.14±1.25	0.92
		200 (n=22)	132.01±6.57	133.67±7.68	<0.001	0.97	-1.19±1.96	0.96
	Breast-stroke	50 (n=50)	32.03±2.32	32.31±2.46	0.001	0.47	-0.82±1.71	1.08
		100 (n=48)	68.88±3.88	69.72±3.67	<0.001	0.61	-1.21±1.71	1.16
		200 (n=27)	145.45±3.40	147.57±4.21	<0.001	0.79	-1.43±1.22	1.14
	Butterfly	50 (n=50)	27.15±1.62	27.24±1.58	0.119	0.22	-0.34±1.56	0.87
		100 (n=28)	59.71±3.56	60.02±3.70	0.016	0.45	-0.49±1.47	0.72
		200 (n=24)	129.59±3.51	130.74±4.00	0.005	0.55	-0.86±1.37	0.93

%, percentage; IMP, performance improvement; CV, intra-swimmer´s coefficient of variation; ES, effect size.

Table 2. Descriptive analysis and rounds effect in men Top16, semi-finalists and finalists.

Event	Swimmers	All rounds (s)				ANOVA		
		Entry	Heats	Semifinals	Final	F-value	p-value	ES
Fr50	Top16	21.70±0.18	21.92±0.13	21.83±0.19	-	18.229	<0.001	0.55
	Semi-finalist	21.72±0.18	21.97±0.14	21.95±0.15	-	23.752	<0.001	0.77
	Finalist	21.67±0.19	21.87±0.11	21.70±0.14	21.63±0.20	6.119	0.004	0.47
Bk50	Top16	24.68±0.40	24.87±0.28	24.69±0.32	-	6.460	0.005	0.30
	Semi-finalist	24.94±0.14	25.11±0.05	24.95±0.16	-	4.567	0.030	0.40
	Finalist	24.42±0.42	24.63±0.19	24.42±0.18	24.48±0.23	2.401	0.147	0.26
Br50	Top16†	27.16±0.47	27.26±0.34	27.18±0.33	-	1.247	0.287	0.08
	Semi-finalist‡	27.43±0.40	27.56±0.08	27.47±0.13	-	0.578	0.490	0.08
	Finalist	26.92±0.40	26.99±0.21	26.92±0.22	26.91±0.34	0.551	0.653	0.07
Fly50	Top16	23.18±0.34	23.09±0.34	23.08±0.22	-	0.622	0.537	0.04
	Semi-finalist	23.26±0.22	23.31±0.18	23.27±0.13	-	0.145	0.866	0.02
	Finalist	23.10±0.42	23.09±0.26	22.90±0.11	22.90±0.22	1.407	0.278	0.17
Fr100	Top16	48.15±0.50	48.30±0.23	47.97±0.46	-	5.462	0.009	0.27
	Semi-finalist	48.47±0.38	48.37±0.15	48.32±0.36	-	0.775	0.478	0.10
	Finalist	47.84±0.42	48.23±0.29	47.62±0.24	47.92±0.28	8.658	0.013	0.55
Bk100	Top16	52.90±0.50	53.57±0.37	53.15±0.68	-	16.125	<0.001	0.52
	Semi-finalist	53.12±0.50	53.81±0.23	53.74±0.30	-	29.900	<0.001	0.81
	Finalist	53.68±0.42	53.34±0.33	52.57±0.34	52.48±0.63	9.932	<0.001	0.59
Br100	Top16	59.24±0.86	59.86±0.64	59.60±0.63	-	15.016	<0.001	0.50
	Semi-finalist	59.74±0.80	60.14±0.57	60.08±0.38	-	3.213	0.071	0.32
	Finalist	58.75±0.61	59.56±0.60	59.12±0.40	59.08±0.55	16.021	<0.001	0.70
Fly100	Top16	51.14±0.60	51.58±0.40	51.31±0.41	-	11.764	0.001	0.44
	Semi-finalist	51.51±0.32	51.86±0.16	51.60±0.16	-	9.069	0.003	0.56
	Finalist	50.77±0.59	51.30±0.37	51.03±0.39	51.06±0.42	4.653	0.012	0.40
Fr200	Top16	105.51±0.80	106.56±0.67	106.13±0.89	-	23.694	<0.001	0.61
	Semi-finalist	105.83±0.90	107.08±0.34	106.81±0.60	-	21.654	<0.001	0.76
	Finalist	105.18±0.56	106.04±0.47	105.45±0.51	104.93±0.82	9.713	0.004	0.58
Bk200	Top16	116.51±1.42	118.02±0.99	117.61±1.54	-	16.347	<0.001	0.52
	Semi-finalist	116.96±1.47	118.59±0.98	118.67±1.48	-	14.000	<0.001	0.67
	Finalist	116.06±1.30	117.45±0.62	116.56±0.56	116.30±1.31	6.362	0.003	0.48
Br200	Top16†	128.56±1.53	130.43±1.04	129.62±1.21	-	23.958	<0.001	0.63
	Semi-finalist‡	129.43±1.50	131.23±0.94	130.58±0.70	-	8.754	0.005	0.59
	Finalist	127.81±1.17	129.74±0.45	128.77±0.89	128.80±0.86	12.224	<0.001	0.64
Fly200	Top16	114.84±1.29	115.89±0.80	115.04±1.04	-	10.570	<0.001	0.41
	Semi-finalist	115.33±0.91	116.21±0.59	115.82±0.50	-	2.886	0.089	0.29
	Finalist	114.34±1.48	115.57±0.88	114.25±0.82	114.10±1.73	8.049	<0.001	0.54

†, n=15; ‡, n=7; Fr, freestyle; Bk, backstroke; Br, breaststroke; Fly, butterfly: ES, effect size; Top16 (n=16); Semi-finalist (n=8); Finalist (n=8).

Current results showed that the majority of male and female swimmers' performances at the Budapest 2022 World Championships were worse than their entry times. This was an extraordinary edition and out of sequence due to the COVID-19 pandemic that also led to the postponement of the Tokyo 2020 Olympics. As the qualification period for this World Championships was set from March to May 2022, several swimmers qualified with times obtained at the Olympic Games. Swimmers participating in World Championships typically have more than a year to prepare for such a demanding event, but as it was just a year after the Tokyo 2020 Olympics, various adjustments to training periodization may have led to ineffective planning (Mujika et al., 2019). While the periodization was changed, a performance setback of 1-2% was found for the Top 50 men who qualified for the 2020 Tokyo Olympics, which was then postponed to 2021 (Costa et al., 2021). In addition, many world-ranked swimmers make some critical decisions after an Olympics event, such as taking a longer rest period (for physical and psychological healing), making more profound changes to their technique (to improve swimming efficiency), or shifting their goals to new swimming events, which require adapting to different training models (Costa et al., 2010). Therefore, this calendar change may not be suitable for elite-level swimmers and some of the reasons mentioned above may explain the course of the competition.

Coaches usually work for a 0.5% improvement margin to achieve a meaningful performance change (Hopkins et al., 1999; Stewart and Hopkins, 2000), but sometimes it takes ~1% performance progression to be at the top of the competition or even to break personal records (Pyne et al., 2004). This type of approach can vary according to the swimmers' career stage, as some are closer to their high-level careers while others have not yet reached that point, which explains why some swimmers find it more difficult to progress within a competition than their peers. Although a %CV > 0.69% was found, the %IMP between entry times and the best performances was negative for most swimming events. In addition, it should be noted that swimmers were grouped according to the FINA A and B qualification standards. As stated, the highest %CV found may be related to the swimmers' competitive level and change based on each round or according to the swimmers' achievements (i.e., the swimmer's final position).

Elite swimmers are likely to participate in various swimming events during a major competition. Most of them occur on the same day or even in the same session of the day. Although progression between rounds is considered necessary and important, it is highly affected by ones' initial performance and may reflect energy conservation rather than the actual performance improvement. So, the swimmers' progression from round-to-round is a key factor to guarantee the qualification for the finals (Arellano et al., 2022). While it has been argued that swimming peak performance should be achieved in the finals (Mujika et al., 2019; Pyne et al., 2004), recent studies have shown that most of the best performances were achieved during the semifinals due to the negative or unchanged %IMP between semifinals and finals (Arellano et al., 2022; Cuenca-Fernández et al., 2021).

These results showed a decrease in performance between entry times and heats in most of the groups due to the negative %IMP (Table 3 and 5). In addition, men and women achieved their best performances in the semifinals with a positive %IMP and highest %CV (i.e., > 0.5%) in all swimming events. As most swimmers want to secure their presence in the ultimate round (i.e., the finals), achieving the best performance at the semifinals should be an expected trend. This agrees with previous studies for the 50 (Arellano et al., 2022), 100, and 200 m events (Cuenca-Fernández et al., 2021). Even so, it should be mentioned that several studies diverge in the analysis of data and in the interpretation of the performance progression. Progression and variability were analyzed according to the semifinalists (16 swimmers), finalists (eight swimmers), or medalists (at least three swimmers) mainly in the Olympic Games (e.g., Issurin et al., 2008; Pyne et al., 2004) and European Championships (e.g., Arellano et al., 2022; Cuenca-Fernández et al., 2021; López-Belmonte et al., 2021). However, the majority of available literature have analyzed the mean differences for %CV (e.g., Cuenca-Fernández et al., 2021), instead of the mean differences for swimming performance (e.g., Arellano et al., 2022). Thus, this is the first study that seeks to understand the mean differences in the progression and variability of the performance of a World Championship according to the Top16, semi-finalists (i.e. eight swimmers), and finalists (i.e. eight swimmers). The semi-finalists tended to have a lower %IMP and %CV when compared to the finalists. This was below the cut-off value (0.5%) to allow for a meaningful change in performance across all events.

Table 3. Percentage of performance improvement and intra-swimmer coefficient of variation between rounds in the men Top16, semi-finalists and finalists.

Event	Swimmers	E-H			H-SF			SF-F		
		p-value	%IMP	%CV	p-value	%IMP	%CV	p-value	%IMP	%CV
	Top16	<0.001	-1.02±0.55	0.72	0.048	0.43±0.63	0.38	-	-	-
Fr50	Semi-finalist	0.002	-1.14±0.57	0.81	1.000	0.11±0.30	0.18	-	-	-
	Finalist	0.013	-0.90±0.54	0.64	0.137	0.75±0.73	0.58	1.000	0.35±0.78	0.44
	Top16	0.048	-0.77±1.14	0.77	0.004	0.74±0.74	0.60	-	-	-
Bk50	Semi-finalist	0.026	-0.66±0.52	0.55	0.156	0.62±0.75	0.58	-	-	-
	Finalist	0.963	-0.88±1.58	0.99	0.093	0.86±0.77	0.62	0.482	-0.22±0.31	0.19
	Top16†	0.698	-0.37±1.12	0.67	0.010	0.28±0.30	0.23	-	-	-
Br50	Semi-finalist‡	1.000	-0.31±1.37	0.74	0.182	0.11±0.82	0.28	-	-	-
	Finalist	1.000	-0.28±0.91	0.60	0.167	0.23±0.24	0.18	1.000	0.07±0.61	0.33
	Top16	1.000	-0.04±1.90	0.97	1.000	0.50±0.84	0.92	-	-	-
Fly50	Semi-finalist	1.000	-0.18±1.23	0.68	1.000	0.17±0.70	0.33	-	-	-
	Finalist	1.000	0.10±2.50	1.12	0.209	0.82±0.89	0.66	1.000	-0.03±0.93	0.56
	Top16	0.639	-0.31±0.94	0.54	0.009	0.70±0.78	0.64	-	-	-
Fr100	Semi-finalist	1.000	0.19±0.70	0.36	1.000	0.12±0.68	0.39	-	-	-
	Finalist	0.243	-0.81±0.91	0.72	<0.001	1.27±0.26	0.89	0.021	-0.63±0.41	0.45
	Top16	<0.001	-1.26±0.76	0.91	0.009	0.80±0.91	0.61	-	-	-
Bk100	Semi-finalist	0.002	-1.28±0.60	0.91	0.945	0.13±0.33	0.18	-	-	-
	Finalist	0.048	-1.23±0.94	0.90	0.007	1.47±0.80	1.03	1.000	0.18±0.95	0.55
	Top16	<0.001	-1.03±0.67	0.76	0.111	0.43±0.75	0.53	-	-	-
Br100	Semi-finalist	0.034	-0.69±0.57	0.55	1.000	0.11±0.80	0.48	-	-	-
	Finalist	0.003	-1.37±0.61	0.98	0.045	0.75±0.57	0.59	1.000	0.07±0.36	0.22
	Top16	0.005	-0.85±0.90	0.71	0.002	0.52±0.99	0.41	-	-	-
Fly100	Semi-finalist	0.025	-0.67±0.52	0.47	0.016	0.51±0.36	0.37	-	-	-
	Finalist	0.254	-1.04±1.18	0.95	0.294	0.53±0.63	0.45	1.000	-0.05±0.33	0.18
	Top16	<0.001	-0.99±0.62	0.70	0.001	0.40±0.35	0.33	-	-	-
Fr200	Semi-finalist	0.002	-1.17±0.55	0.83	0.460	0.25±0.44	0.27	-	-	-
	Finalist	0.069	-0.81±0.67	0.57	<0.001	0.56±0.14	0.39	0.136	0.49±0.48	0.39
	Top16	<0.001	-1.28±1.03	0.94	0.281	0.35±0.77	0.62	-	-	-
Bk200	Semi-finalist	0.026	-1.37±1.08	0.98	1.000	-0.06±0.80	0.47	-	-	-
	Finalist	0.093	-1.18±1.05	0.90	0.016	0.76±0.48	0.57	1.000	0.22±0.82	0.44
	Top16†	<0.001	-1.43±0.96	1.08	<0.001	0.63±0.51	0.49	-	-	-
Br200	Semi-finalist‡	0.042	-1.06±1.31	1.04	0.092	-0.17±1.12	0.43	-	-	-
	Finalist	0.018	-1.49±0.94	1.11	0.031	0.75±0.54	0.53	1.000	-0.02±0.43	0.27
	Top16	0.002	-0.91±0.86	0.73	0.002	0.75±0.70	0.63	-	-	-
Fly200	Semi-finalist	0.107	-0.76±0.82	0.65	0.606	0.34±0.67	0.45	-	-	-
	Finalist	0.083	-1.06±0.93	0.82	0.001	1.16±0.45	0.81	1.000	0.14±0.85	0.44

†, n=15; ‡, n=7; Fr, freestyle; Bk, backstroke; Br, breaststroke; Fly, butterfly; E, entry times; H, heats; SF, semifinals; F, finals; %, percentage; IMP, performance improvement; CV, intra-swimmer´s coefficient of variation.

Table 4. Descriptive analysis and rounds effect in women Top16, semi-finalists and finalists.

Event	Swimmers	All rounds (s)				ANOVA		
		Entry	Heats	Semifinals	Final	F-value	p-value	ES
Fr50	Top16†	24.58±0.30	24.92±0.29	24.76±0.36	-	21.305	<0.001	0.60
	Semi-finalist‡	24.80±0.24	25.15±0.18	25.06±0.15	-	6.370	0.013	0.52
	Finalist	24.39±0.20	24.73±0.22	24.49±0.26	24.48±0.31	21.356	<0.001	0.75
Bk50	Top16	27.73±0.53	27.93±0.34	27.71±0.35	-	4.554	0.019	0.23
	Semi-finalist	28.12±0.42	28.16±0.22	27.99±0.24	-	1.096	0.336	0.14
	Finalist	27.34±0.27	27.71±0.28	27.43±0.17	27.50±0.17	6.053	0.027	0.46
Br50	Top16†	30.41±0.50	30.53±0.41	30.43±0.38	-	0.660	0.525	0.05
	Semi-finalist‡	30.62±0.29	30.79±0.13	30.78±0.19	-	2.443	0.129	0.29
	Finalist	30.23±0.58	30.30±0.44	30.13±0.19	30.12±0.28	0.504	0.610	0.07
Fly50	Top16	25.83±0.44	26.04±0.34	25.82±0.41	-	9.149	<0.001	0.38
	Semi-finalist	26.15±0.31	26.28±0.20	26.15±0.26	-	1.914	0.184	0.22
	Finalist	25.50±0.26	25.79±0.27	25.49±0.19	25.44±0.28	8.345	<0.001	0.54
Fr100	Top16	53.50±0.72	54.15±0.33	53.80±0.59	-	13.392	<0.001	0.47
	Semi-finalist	53.91±0.70	54.36±0.19	54.29±0.29	-	2.608	0.144	0.27
	Finalist	53.08±0.48	53.95±0.31	53.31±0.35	53.24±0.44	30.516	<0.001	0.81
Bk100	Top16	59.40±0.89	60.12±0.84	59.93±0.99	-	24.235	<0.001	0.62
	Semi-finalist	59.93±0.52	60.80±0.26	60.69±0.44	-	19.327	0.002	0.73
	Finalist	58.87±0.88	59.44±0.61	59.17±0.77	59.38±0.80	7.656	0.001	0.52
Br100	Top16†	65.94±0.63	66.75±0.38	66.38±0.41	-	13.473	<0.001	0.49
	Semi-finalist‡	66.15±0.50	66.83±0.39	66.72±0.25	-	8.524	0.005	0.59
	Finalist	65.74±0.69	66.67±0.37	66.08±0.27	66.22±0.25	6.279	0.003	0.47
Fly100	Top16	57.32±1.09	58.12±0.79	57.72±0.83	-	13.663	<0.001	0.48
	Semi-finalist	58.09±0.71	58.63±0.61	58.38±0.51	-	2.317	0.135	0.25
	Finalist	56.54±0.81	57.62±0.61	57.07±0.51	56.81±0.89	15.836	<0.001	0.69
Fr200	Top16†	116.72±1.35	117.86±0.67	117.09±0.78	-	10.273	<0.001	0.42
	Semi-finalist‡	117.75±0.51	118.13±0.59	117.69±0.72	-	1.643	0.245	0.22
	Finalist	115.82±1.21	117.63±0.68	116.56±0.30	116.46±0.94	10.714	<0.001	0.61
Bk200	Top16	128.81±3.02	131.20±2.35	130.38±2.79	-	26.825	<0.001	0.64
	Semi-finalist	131.26±1.58	133.01±1.71	132.51±1.85	-	7.587	0.006	0.52
	Finalist	126.37±1.84	129.40±1.21	128.26±1.61	127.75±2.04	18.787	<0.001	0.73
Br200	Top16	143.45±2.25	146.19±1.21	145.10±1.73	-	29.810	<0.001	0.67
	Semi-finalist	144.86±2.18	147.14±0.85	146.50±1.05	-	8.886	0.014	0.56
	Finalist	142.05±1.26	145.24±0.61	143.71±0.93	143.95±1.20	19.724	<0.001	0.74
Fly200	Top16	127.62±1.96	129.63±1.32	128.74±1.96	-	12.417	<0.001	0.45
	Semi-finalist	128.41±1.79	130.45±1.09	130.27±1.45	-	9.320	0.003	0.57
	Finalist	126.83±1.90	128.81±1.01	127.21±0.87	126.94±1.06	7.068	0.023	0.50

†, n=15; ‡, n=7; Fr, freestyle; Bk, backstroke; Br, breaststroke; Fly, butterfly: ES, effect size. Top16 (n=16); Semi-finalist (n=8); Finalist (n=8).

When grouping, the Top16 can lead to a misinterpretation of progression and variability in performance. For example, the Fr50 men's performance remained unchanged in semi-finalists and finalists between heats and semifinals, but the Top16 showed a substantial decrease in swimming performance (Table 3). It is understandable that the absence of group comparison within each round can been seen as a limitation but should be a seen as a topic of interest in the future.

While the semifinals appear to be the round to excel, there is a chance to see different performance improvements over the previous round (i.e., the heats). As mentioned earlier, some swimmers will strive more than others to perform well in the semifinals. The explanation of the different trends may depend on the effort that some swimmers have already exhibited near their limit, as argued above (Arellano et al., 2022). While some swimmers had reached or were approaching their maximum energy and technical status, any margin for further improvement between rounds is very small. In fact, the technical aspects of the stroke do not seem to differ between medalists and non-medalists (Jesus et al., 2011). So, it can be argued that the finalists are the ones who have the ability to conserve energy and manage to show a ~1% improvement in the semifinal round in most events.

Future studies should focus on swimmers' analysis considering the entry times and the ranking positioning. The relations between that date of the entry times and the difference obtained in performances during the main competition still is a topic to be explored. The energetic or kinematic behavior between rounds should also be a point of interest to properly understand swimmers' strategies in a World-Class competition.

Conclusion

Swimmers who qualified for the 2022 World Championships in the 50, 100, and 200 m freestyle, backstroke, breaststroke, and butterfly showed negative progression between their entry times and the best performance achieved within the competition. The finalists appear to be able to make significant progress in performance in the semifinals (~1% improvement), while the semifinalists (females and male swimmers) showed variations below 0.5% in most events. The variability tended to decrease between rounds for both female and male swimmers making each round more homogeneous and competitive.

Table 5. Percentage of performance improvement and intra-swimmer coefficient of variation between rounds in the women Top16, semifinalists and finalists.

Event	Swimmers	E-H			H-SF			SF-F		
		p-value	%IMP	%CV	p-value	%IMP	%CV	p-value	%IMP	%CV
Fr50	Top16†	<0.001	-1.38±1.10	1.01	0.002	0.36±0.75	0.59	-	-	-
	Semi-finalist‡	0.050	-0.82±1.26	1.07	0.754	0.13±0.42	0.48	-	-	-
	Finalist	<0.001	-1.35±0.45	0.96	<0.001	0.97±0.29	0.68	1.000	1.04±0.47	0.26
Bk50	Top16	0.206	-0.74±1.51	0.88	<0.001	0.81±0.56	0.57	-	-	-
	Semi-finalist	1.000	-0.14±1.43	0.74	0.013	0.58±0.40	0.41	-	-	-
	Finalist	0.189	-1.34±1.41	1.02	0.013	1.03±0.62	0.73	0.433	-0.26±0.35	0.26
Br50	Top16†	1.000	-0.37±1.64	0.97	0.844	0.32±1.09	0.54	-	-	-
	Semi-finalist‡	0.559	-0.54±0.96	0.66	1.000	0.05±0.58	0.32	-	-	-
	Finalist	1.000	0.40±0.52	1.24	1.000	0.55±1.40	0.73	1.000	0.06±0.45	0.24
Fly50	Top16	0.012	-0.81±0.95	0.73	0.004	0.86±0.87	0.69	-	-	-
	Semi-finalist	0.429	-0.50±0.86	0.48	0.119	0.52±0.58	0.45	-	-	-
	Finalist	0.090	-1.12±0.99	0.99	0.074	1.20±1.01	0.94	1.000	0.21±0.66	0.42
Fr100	Top16	<0.001	-1.22±1.02	0.99	0.003	0.66±0.65	0.53	-	-	-
	Semi-finalist	0.314	-1.36±0.79	0.84	1.000	0.68±0.62	0.23	-	-	-
	Finalist	<0.001	-1.61±0.56	1.15	<0.001	1.19±0.31	0.83	1.000	0.13±0.34	0.23
Bk100	Top16	<0.001	-1.18±0.71	0.84	0.040	0.32±0.45	0.33	-	-	-
	Semi-finalist	0.001	-1.42±0.65	1.02	0.790	0.19±0.42	0.28	-	-	-
	Finalist	0.044	-0.95±0.72	0.67	0.168	0.46±0.47	0.38	0.957	-0.36±0.65	0.42
Br100	Top16†	0.002	-1.21±1.06	0.95	0.017	0.55±0.66	0.45	-	-	-
	Semi-finalist‡	0.058	-1.01±0.85	0.79	1.000	0.17±0.48	0.26	-	-	-
	Finalist	0.097	-1.39±1.25	1.09	0.029	0.89±0.62	0.62	0.942	-0.21±0.37	0.24
Fly100	Top16	0.003	-1.39±1.34	1.20	0.015	0.69±0.84	0.61	-	-	-
	Semi-finalist	0.417	-0.91±1.55	1.01	0.699	0.43±0.93	0.51	-	-	-
	Finalist	0.006	-1.87±0.97	1.36	0.039	0.96±0.70	0.72	1.000	0.47±0.85	0.57
Fr200	Top16†	0.006	-0.97±0.99	0.76	0.005	0.66±0.65	0.56	-	-	-
	Semi-finalist‡	0.771	-0.32±0.69	0.38	0.612	0.38±0.69	0.43	-	-	-
	Finalist	0.011	-1.54±0.89	1.10	0.011	0.92±0.53	0.67	1.000	0.09±0.83	0.48
Bk200	Top16	<0.001	-1.83±1.16	1.32	0.044	0.64±0.93	0.62	-	-	-
	Semi-finalist	0.020	-1.31±0.98	0.96	0.824	0.39±0.92	0.52	-	-	-
	Finalist	0.004	-2.34±1.16	1.68	0.168	0.89±0.92	0.72	0.380	0.40±0.52	0.34
Br200	Top16	<0.001	-1.87±1.14	1.35	<0.001	0.75±0.63	0.54	-	-	-
	Semi-finalist	0.035	-1.55±1.29	1.12	0.113	0.44±0.48	0.34	-	-	-
	Finalist	0.002	-2.19±0.95	1.57	0.010	1.07±0.62	0.75	1.000	-0.16±0.50	0.23
Fly200	Top16	0.001	-1.55±1.34	1.20	0.005	0.70±0.74	0.58	-	-	-
	Semi-finalist	0.037	-1.56±1.32	1.24	1.000	0.15±0.57	0.28	-	-	-
	Finalist	0.127	-1.53±1.46	1.15	<0.001	1.26±0.35	0.88	-	-	-

†, n=15; ‡, n=7; Fr, freestyle; Bk, backstroke; Br, breaststroke; Fly, butterfly; E, entry times; H, heats; SF, semifinals; F, finals; %, percentage; IMP, performance improvement; CV, intra-swimmer´s coefficient of variation.

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References

Arellano, R., Ruiz-Navarro, J. J., Barbosa, T. M., López-Contreras, G., Morales-Ortíz, E., Gay, A., López-Belmonte, Ó., González-Ponce, Á. and Cuenca-Fernández, F. (2022) Are the 50 m Race Segments Changed From Heats to Finals at the 2021 European Swimming Championships? *Frontiers in Physiology* **13**, 797367. https://doi.org/10.3389/fphys.2022.797367

Barbosa, T. M., Barbosa, A. C., Simbaña Escobar, D., Mullen, G. J., Cossor, J. M., Hodierne, R., Arellano, R. and Mason, B. R. (2021) The role of the biomechanics analyst in swimming training and competition analysis. *Sports Biomechanics*, in press. https://doi.org/10.1080/14763141.2021.1960417

Born, D.-P., Lomax, I., Horvath, S., Meisser, E., Seidenschwarz, P., Burkhardt, D. and Romann, M. (2020) Competition-Based Success Factors During the Talent Pathway of Elite Male Swimmers. *Frontiers in Sports and Active Living* **2**. https://doi.org/10.3389/fspor.2020.589938

Coolican, H. (2009) *Research methods and statistics in psychology*. Hodder, London, United Kingdom.

Costa, M. J., Garrido, N. D., Marinho, D. A. and Santos, C. C. (2021) How Much the Swimming Performance Leading to Tokyo 2020 Olympic Games Was Impaired Due to the Covid-19 Lockdown? *Journal of Sports Science & Medicine* **20**(4), 714–720. https://doi.org/10.52082/jssm.2021.714

Costa, M. J., Marinho, D. A., Reis, V. M., Silva, A. J., Marques, M. C., Bragada, J. A. and Barbosa, T. M. (2010) Tracking the performance of world-ranked swimmers. *Journal of Sports Science & Medicine* **9**, 411–417. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3761712/

Cuenca-Fernández, F., Ruiz-Navarro, J. J., González-Ponce, A., López-Belmonte, O., Gay, A. and Arellano, R. (2021) Progression and variation of competitive 100 and 200m performance at the 2021 European Swimming Championships. *Sports Biomechanics*, in press. https://doi.org/10.1080/14763141.2021.1998591

Ferguson, C. J. (2009) An effect size primer: A guide for clinicians and researchers. *Professional Psychology, Research and Practice* **40,** 532–538. https://doi.org/10.1037/a0015808

Fritz, C. O., Morris, P. E. and Richler, J. J. (2012) Effect size estimates: current use, calculations, and interpretation. *Journal of Experimental Psychology: General* **141,** 2–18. https://doi.org/10.1037/a0024338

Hopkins, W. G., Hawley, J. A., and Burke, L. M. (1999) Design and analysis of research on sport performance enhancement. *Medicine and Science in Sports and Exercise* **31**, 472–485. https://doi.org/10.1097/00005768-199903000-00018

Issurin, V., Kaufman, L., Lustig, G. and Tenenbaum, G. (2008) Factors affecting peak performance in the swimming competition of the Athens Olympic Games. *Journal of Sports Medicine and Physical Fitness* **48**, 1–8.

Jesus, S., Costa, M. J., Marinho, D. A., Garrido, N. D., Silva, A. J. and Barbosa, T. M. (2011) 13th FINA World Championship finals: stroke kinematical and race times according to performance, gender and event. *Portuguese Journal of Sport Sciences*, 275–278. Biomechanics in Sports 29. Porto, Portugal.

López-Belmonte, Ó., Gay, A., Ruiz-Navarro, J. J., Cuenca-Fernández, F., González-Ponce, Á., & Arellano, R. (2021) Pacing profiles, variability and progression in 400, 800 and 1500-m freestyle swimming events at the 2021 European Championship. *International Journal of Performance Analysis in Sport* **22**, 90–101. https://doi.org/10.1080/24748668.2021.2010318

Mauger, A. R., Neuloh, J. and Castle, P. C. (2012) Analysis of pacing strategy selection in elite 400-m freestyle swimming. *Medicine and Science in Sports and Exercise* **44**, 2205–2212. https://doi.org/10.1249/MSS.0b013e3182604b84

Mohamed, T. J., zied, A., Cuenca-Fernández, C. and Abderraouf, B. A. (2021) Physiological, perceptual responses, and strategy differences in age-group swimmers between heats and semi-finals in the 400 metres freestyle event. *International Journal of Performance Analysis in Sport* **21**, 953–964. https://doi.org/10.1080/24748668.2021.1963107

Mujika, I., Padilla, S. and Pyne, D. (2002) Swimming Performance Changes During the Final 3 Weeks of Training Leading to the Sydney 2000 Olympic Games. *International Journal of Sports Medicine* **23**, 582–587. https://doi.org/10.1055/s-2002-35526

Mujika, I., Villanueva, L., Welvaert, M. and Pyne, D. B. (2019) Swimming Fast When It Counts: A 7-Year Analysis of Olympic and World Championships Performance. *International Journal of Sports Physiology and Performance* **14**, 1132–1139. https://doi.org/10.1123/ijspp.2018-0782

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

Stewart, A. M. and Hopkins, W. G. (2000) Consistency of swimming performance within and between competitions. *Medicine & Science in Sports & Exercise* **32**, 997–1001. https://doi.org/10.1097/00005768-200005000-00018

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Key points

- Swimming performance declines between entry and best performance achieved during the 2022 FINA World Championships.
- The progression from the heats to the semifinals (~1% IMP) seems to be determinant to reach the finals.
- Performance variability tends to decrease from round to round.

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