Analysis of the Personal Best Swim Times: 2016 Rio Olympics

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Abstract

Olympic games are the pinnacle of elite swimmers' careers where they strive to peak and produce personal best (PB) times. The Olympics provides a unique benchmark to assess successfulness of preparation regimes. The aim of this research was to quantify the likelihood of producing a PB and the expected magnitude of improvement. We analysed relative swim performance gain (RSPG%) or decrement from PB time using data from 793 swimmers (1075 event entries) competing in the 13 male and female individual events of the 2016 Rio Olympics. Analysis of variance (ANOVA) and hierarchical linear regression were performed to estimate the effect of gender, stroke-type, swimming distance, age, and days since PB, on PB times. We found 339 (31.5%) swimmers produced a PB time during the games. Mean PB improvement was 1.6 ± 3.2% faster, with PB times coming 437 ± 473 days following their previous PB. Gold medallists had ~81% PB success rate. Those failing to set a PB swam 1.5 ± 1.4% slower than their actual PB. The 50m Freestyle was associated with the greatest RSPG% improvement (Males 0.3%, females 1.5% faster). Combining our data with knowledge of actual preparation strategies employed by specific swimmers or teams will allow assessment of the relative success of an approach.

Introduction

Immediately post-2012 London Olympics, controversy erupted after the journal Nature published a commentary describing the world record 400m individual medley performance of 16-year old Chinese swimmer Ye Shiwen at the games as 'anomalous' (4). Callaway's suggestion that an athlete's performance history and the limits of human physiology may be used to catch dopers drew criticism for using Ye as a case study while not undertaking due diligence in accurately determining what constituted a typical improvement of a PB time (15). Ultimately, the debate resulted in an apology to Ye from Nature's editors. This episode demonstrates the pertinent need to better understand performance profiling and how the critical confounding factor of maturation affects a swimmer's rate of improvement. Indeed, Pyne et al., (10) mention that estimates of progression and variability of athletic performance in competitions are useful for researchers and practitioners interested in factors that affect performance.

A plethora of factors including illness, injury, the ability to psychologically cope with the big occasion, and even the pool itself through lane bias (3, 5) may sabotage a potential PB. The fact that the Olympic games occurs on a quadrennial cycle adds to the pressure of getting the peak right. Previously, it has been shown that on average swimmers swum ~0.6 ± 1.1% slower in the Athens Olympics compared to their final stage preparation phase prior to the Olympics (7). Factors including the heightened emotional strain and anxiety, hormonal and metabolic changes induced by stress and training insufficiency during final stage preparations were suggested as possible reasons for the performance decrement (7).

In contrast, other studies have reported an overall performance improvement by swimmers at the Olympics. Pyne et al., (10) showed that at the 2000 Sydney Olympics, both the Australian and United States swim teams had an overall improvement (0.6 and 0.2 % faster, respectively) from their Olympic Trials. A considerable amount of training theory is based on the concept of peaking for competition through the implementation of a taper. The primary aim of the taper should be the elimination of accumulated fatigue, rather than to attain additional physiological adaptations or fitness gains, and should be achieved without compromising previously acquired adaptations and fitness level (8). The timing of when selection trials are held is often a contentious issue and ultimately influences the training plan implementation and impacts on the subsequent overall performances of countries in the Olympics (7).

Relative gain in swimming performance can be easily calculated and this indicator of performance increment or decrement is regarded as the ultimate estimation of peaking (7). Using the individual pool swimming events of the 2016 Rio de Janeiro Olympic competition, the aim of this study was to quantify the magnitude of improvements of swimmers with successful performances (new PB) while also reporting the degree to which performance is compromised when the plan goes wrong. This data will help to estimate expected performance improvements, predict future winning times, and may influence training and tapering decisions.

Methods

The study included all 13 male and female individual pool swimming events at the Rio 2016 Olympic games. These were: 50m, 100m, 200m, 400m, 800m (females only) and 1500m (males only) freestyle; 100m and 200m butterfly; 100m and 200m breaststroke; 100m and 200m backstroke; 200m and 400m individual medley. Criteria for swimmers to be included in the study required them to obtain an official finish time result. Six athletes failed this criteria, resulting in a total sample size of 793 (426 males, 367 females) swimmers representing 173 different nations. Athlete's that took part in multiple events were treated as individual cases (1075 cases). The Olympic Games format usually consists of heats, semi-finals and final races. But certain events such as the 800m Freestyle contained only heats and a final. The swimmers' times for every stage of an event were recorded. For each event, swimmers were assigned an Olympic performance rank using one of four categories: 1 – medal winners, finishing in places 1st to 3rd; 2 – finalists, finishing 4th to 8th; 3 – semi-finalists, finishing 9th to 16th; and 4 – other Olympians, finishing 17th or lower place. Dates for the athlete's times achieved at the Rio 2016 Olympic Games were all given the generic first official date of the swimming schedule (6th August 2016).

Every athlete sampled had their pre-Olympic Games official PB time and associated date that this was achieved recorded. These results were obtained from either the Federation Internationale de Natation Amateur (FINA) or from the swimmers national governing swimming body. These official results were from FINA recognized events which were acceptable for Olympic standard qualification and were registered in Olympic standard 50m length pools. All times and data were collated into a customised spreadsheet for analysis (Microsoft Excel, Microsoft Corporation, Redmond, Washington).

Relative differences between the pre-Olympic swimming PB and the fastest official Olympic competition result expressed as a percentage (RSPG%) were calculated to determine the success of the preparation. Descriptive statistics were computed for RSPG% with respect to event, nation, stroke-type, Olympic rank, distance, gender, age category (≤ 19 years, 20 – 24 years, ≥ 25 years) and days since PB category (≤365 days, 366-731 days, ≥732 days). Mean discrepancy or improvement in Olympic times from prior PB results were calculated to understand the magnitude of changes. An analysis of variance (ANOVA) and hierarchical linear regression were performed to determine factors influencing RSPG% in the Olympic swimming competition. These procedures were similar to prior research completed by Issurin et al. (7).

Discussion

Overall, when assessed across all 1075 event entries the RSPG% was -0.5 ± 2.6% (slower) at the Rio Olympics was compared with prior PB times. We found that 339 (31.5%) swimmers produced a PB time during the games with a similar chance of producing a PB by gender (183, 32.6% males vs. 156, 30.3% females). The mean PB improvement was 1.6 ± 3.2% faster, with PB times coming 437 ± 473 days following their previous PB. By contrast, those that failed to produce a PB at the Rio Olympics performed 1.5 ± 1.4% slower than their PB. These unsuccessful athletes also produced their most current PB time 662 ± 767 days prior to the games. Table 1, details the RSPG% break down across all of the individual swimming events, categorized by gender.

We compared the same 24 nations that were previously compared at the 2004 Athens Olympics by Issurin et al. (7). Across this selection, Croatia was the only nation that achieved a positive RSPG% (swam faster), however they had a very small number (4) of event entries. At the other end of the spectrum, Israel and Austria were the only two nations to swim more than 2% slower than their previously recorded mean PB times. The percentage of PBs achieved in comparison to event entries ranged from 0 to 50%, with the United States, Japan and New Zealand the top three performing nations in this statistic. Israel and the Czech Republic failed to produce any new PBs at the Rio Olympics. Please refer to Table 2 for additional country comparisons.

Table 1. Event specific relative swimming performance gain (Mean ± SD)

Gender	Event	Entries (#)	Age (Y)	RSPG (%)	PBs (#)	PB success Rate (%)	Days since last PB (New Rio PB)	Days since last PB (No Rio PB)
Male	50m Freestyle	85	23.0 ± 4.3	0.3 ± 3.7	37	44	491 ± 434	709 ± 796
	100m Freestyle	59	23.2 ± 3.2	-0.5 ± 1.4	19	32	352 ± 256	701 ± 748
	200m Freestyle	47	22.8 ± 3.3	-0.6 ± 1.4	18	38	362 ± 158	915 ± 953
	400m Freestyle	50	22.2 ± 3.0	-0.8 ± 1.6	15	30	618 ± 926	720 ± 876
	1500m Freestyle	45	21.5 ± 3.2	-0.9 ± 1.5	14	31	326 ± 339	553 ± 806
	100m Butterfly	43	23.9 ± 4.2	-1.0 ± 1.8	9	21	225 ± 130	737 ± 898
	200m Butterfly	29	23.5 ± 3.8	-0.7 ± 1.0	8	28	373 ± 436	957 ± 944
	100m Backstroke	39	21.8 ± 3.6	-0.5 ± 1.4	14	36	406 ± 361	391 ± 464
	200m Backstroke	26	22.3 ± 2.9	-0.8 ± 1.3	9	35	216 ± 219	754 ± 920
	100m Breaststroke	46	23.7 ± 3.2	-0.6 ± 1.3	11	24	450 ± 292	590 ± 691
	200m Breaststroke	39	22.9 ± 3.2	-0.8 ± 1.3	10	26	415 ± 224	688 ± 744
	200m Individual Medley	27	24.6 ± 3.2	-0.4 ± 1.2	8	30	510 ± 272	946 ± 846
	400m Individual Medley	26	23.1 ± 3.3	-0.4 ± 1.4	11	42	558 ± 764	843 ± 966
	Overall	**561**	**23.0 ± 0.4**	**-0.6 ± 0.6**	**183**	**33**	**408 ± 224**	**731 ± 133**
Female	50m Freestyle	87	22.0 ± 4.6	1.5 ± 5.7	36	41	604 ± 546	539 ± 550
	100m Freestyle	46	22.4 ± 4.1	-0.6 ± 1.5	17	37	285 ± 223	525 ± 480
	200m Freestyle	43	21.4 ± 3.9	-0.6 ± 2.8	16	37	460 ± 460	660 ± 852
	400m Freestyle	32	21.9 ± 4.0	-0.8 ± 2.8	11	34	738 ± 1026	707 ± 665
	800m Freestyle	27	22.0 ± 3.9	-0.9 ± 1.1	5	19	677 ± 561	554 ± 635
	100m Butterfly	45	21.9 ± 3.5	-0.7 ± 1.4	13	29	219 ± 135	519 ± 577
	200m Butterfly	27	22.7 ± 3.7	-0.6 ± 1.4	10	37	366 ± 194	656 ± 602
	100m Backstroke	34	21.7 ± 3.7	-0.9 ± 1.8	12	35	435 ± 379	584 ± 775
	200m Backstroke	28	23.0 ± 3.8	-1.5 ± 1.8	7	25	375 ± 223	959 ± 832
	100m Breaststroke	44	21.4 ± 3.4	-1.1 ± 2.1	10	23	380 ± 239	516 ± 497
	200m Breaststroke	29	22.4 ± 3.3	-1.0 ± 1.6	7	24	353 ± 240	449 ± 599
	200m Individual Medley	39	22.3 ± 3.9	-1.5 ± 1.3	4	10	280 ± 247	790 ± 974
	400m Individual Medley	33	22.7 ± 3.7	-1.1 ± 1.7	8	24	728 ± 812	568 ± 669
	Overall	**514**	**22.1 ± 0.3**	**-0.7 ± 1.2**	**156**	**30**	**454 ± 258**	**617 ± 142**

Table 2. Nation specific relative swimming performance gain (Mean ± SD)

Nation	Entries (#)	RSPG (%)	PBs (#)	PB Success Rate (%)	Days since last PB (New Rio PB)
United States	52	-0.3 ± 1.0	26	50	275 ± 357
Australia	49	-0.7 ± 1.2	10	20	531 ± 557
Japan	42	-0.2 ± 1.3	21	50	553 ± 300
Russia	42	-1.0 ± 1.1	9	21	245 ± 244
Hungary	40	-1.1 ± 1.3	8	20	276 ± 217
Canada	34	-0.5 ± 1.3	11	32	177 ± 108
Great Britain	34	-0.3 ± 0.9	11	32	252 ± 248
Italy	33	-1.6 ± 1.2	3	9	683 ± 814
Germany	27	-1.0 ± 1.2	6	22	411 ± 257
Spain	26	-1.0 ± 1.6	5	19	1202 ± 1407
Poland	20	-1.8 ± 1.4	1	5	70
Sweden	16	-1.0 ± 1.2	4	25	858 ± 991
New Zealand	15	-0.1 ± 0.9	7	47	363 ± 306
Denmark	15	-1.0 ± 1.4	4	27	877 ± 1005
Israel	14	-2.6 ± 3.3	0	0	-
Switzerland	12	-0.7 ± 1.2	4	33	142 ± 130
Czech Republic	12	-1.4 ± 0.8	0	0	-
Finland	11	-0.9 ± 1.0	3	27	378 ± 15
South Korea	11	-1.4 ± 1.7	2	18	203 ± 168
Slovenia	9	-1.3 ± 1.3	1	11	72
Austria	8	-2.0 ± 1.2	1	13	477
Ukraine	8	-1.3 ± 1.1	1	13	55
Romania	5	-0.5 ± 1.1	2	40	60 ± 23
Croatia	4	0.1 ± 1.4	1	25	246

Across stroke-types freestyle events displayed the mean performance closest to their PB, although the RSPG% (-0.2 ± 3.3%), was still negative indicating an overall decline in performance. Swimmers in the breaststroke and backstroke events found it hardest to get close to their PB, with the overall decline in performance approaching 1% slower. More than a third of entries in the freestyle events produced PBs, whereas ~ only a fifth could manage a PB in the breaststroke events. Medal winners were the only Olympic rank to swim faster than their mean PB with a positive 0.2 ± 0.9% improvement (see Figure 1). All other Olympic rankings produced mean negative RSPG% which indicates a decline in performance, hence slower times than their pre-Olympic PB. Unsurprisingly, medal winners also had the highest PB success rate with almost two thirds setting new PBs during the games. With one exception, the longer the event distance the greater the PB success rate. The exception to this observation was the 50m sprint races, which incidentally were the only distance classification to show a mean positive RSPG% (0.8 ± 5.0%).

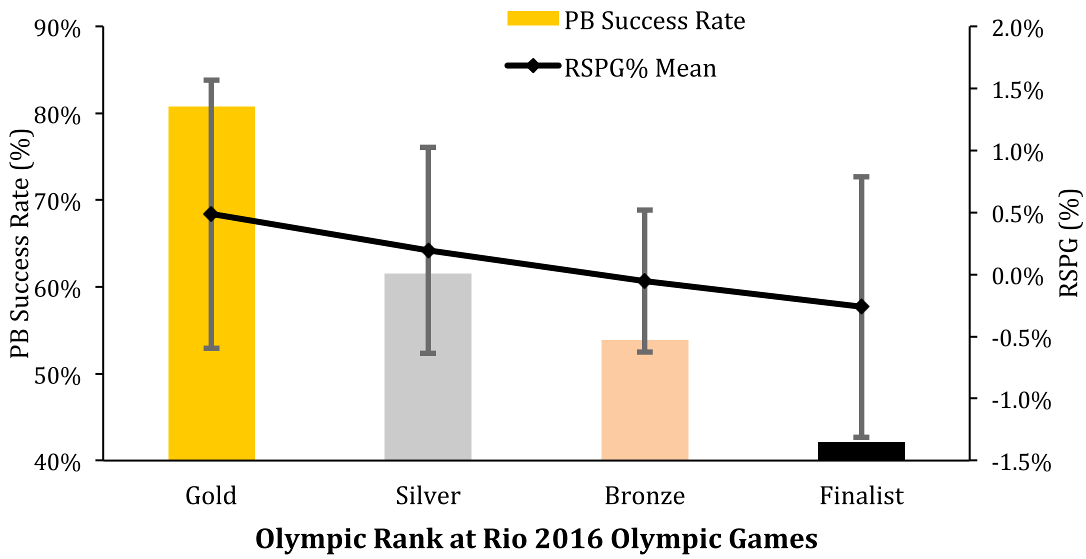

Figure 1. Relative swim performance gain % (mean +/- SD) and the success rate of attaining a personal best for individual swim event medalists and other finalists (positioned 4 to 8) at the Rio 2016 Olympic Games

Younger swimmers (≥ 19 years) produced a better PB success rate than older aged swimmers and were the only age category to have a mean positive RSPG% (0.3 ± 4.0%). Finally, almost half (44%) of those swimmers whose last PB was achieved between 1 - 2 years ago produced a PB in Rio. Interestingly, while almost a third of swimmers that produced a PB within the last 12 months repeated the feat in Rio, this ratio falls away dramatically with less than a fifth of swimmers getting a Rio PB when they last produced the feat more than two years ago (Refer to Table 3).

We performed an ANOVA comparing factors that could influence mean RSPG%. Four of the variables were statistically significant in influencing swimmers RSPG% mean scores: stroke-type, Olympic rank, distance and age ($P<0.01$). Subsequently, we completed a hierarchical linear regression to assess the variance influence of these factors. Of the six variables tested, 9.2% of the variance could be attributed to four factors: stroke-type, Olympic rank, distance and age ($P<0.01$). The regression results are displayed in Table 4.

Table 3. Specific relative swimming performance gain by stroke-type, Olympic rank, distance, gender, age and days since PB (Mean ± SD)

		Entries (#)	RSPG (%)	PBs (#)	PB Success Rate (%)	Days since last PB (New Rio PB)
Stroke-Type	Freestyle	521	-0.2 ± 3.3	189	36	437 ± 475
	Butterfly	144	-0.7 ± 1.5	42	29	363 ± 345
	Backstroke	127	-0.9 ± 1.7	37	29	454 ± 479
	Breaststroke	158	-0.9 ± 1.6	34	22	418 ± 369
	Medley	125	-0.7 ± 1.6	37	30	521 ± 632
Olympic Rank	Medal Winners (1st-3rd Place)	78	0.2 ± 0.9	51	65	409 ± 370
	Finalists (4th-8th Place)	133	-0.3 ± 1.1	56	42	369 ± 473
	9th-16th Place	205	-0.4 ± 1.4	67	33	534 ± 644
	17th Place and above	659	-0.7 ± 3.1	165	25	430 ± 410
Distance (m)	50	172	0.8 ± 5.0	67	39	482 ± 420
	100	356	-0.8 ± 1.6	102	29	433 ± 461
	200	334	-0.8 ± 1.5	96	29	375 ± 431
	400	141	-0.7 ± 1.9	44	31	553 ± 693
	800	27	-0.3 ± 1.3	11	41	496 ± 248
	1500	45	-0.5 ± 1.5	19	42	315 ± 273
Gender	Male	561	-0.5 ± 2.0	183	33	433 ± 456
	Female	514	-0.5 ± 3.1	156	30	442 ± 493
Age Band (Years)	≤ 19	250	0.3 ± 4.0	104	42	381 ± 328
	20 – 24	422	-0.3 ± 2.0	159	38	391 ± 374
	≥ 25	403	-1.2 ± 1.6	76	19	610 ± 722
Days Since PB (Days)	≤ 365	504	-0.6 ± 2.0	155	31	153 ± 112
	366 – 731	314	0.1 ± 3.0	139	44	459 ± 136
	≥ 732	257	-1.2 ± 2.7	45	18	1350 ± 690

Table 4. Hierarchical linear regression results for RSPG% by stroke type, Olympic rank, distance, gender, age and days since PB

Model	R	R Square	Adjusted R Square	Change Statistics			
				R Square Change	F Change	df	Sig. F Change
A. Stroke-Type	0.118	0.014	0.013	0.014	15.02	1073	0
B. A + Olympic Rank	0.166	0.027	0.026	0.014	15.019	1072	0
C. A + B + Distance	0.230	0.053	0.050	0.025	28.633	1071	0
D. A + B + C + Gender	0.230	0.053	0.049	0.000	0.077	1070	0.782
E. A + B + C + D + Age	0.303	0.092	0.087	0.039	45.603	1069	0
F. A + B + C + D + E + Days since PB	0.305	0.093	0.088	0.001	1.565	1068	0.211

Combined, across all individual swimming events at the Rio 2016 Olympic Games the mean RSPG% (-0.5 ± 2.6%) indicated that on average swimmers were slower than their pre-Olympic PB. The only event which demonstrated an overall faster swim time and hence improved or positive RSPG% score was the 50m Freestyle (Males 0.3% and females 1.5% faster); more on that later. The current study, explored the magnitude of improvements for swimmers at the Olympic Games and demonstrates that a majority of swimmers have a performance decrement in relation to their PB (68.5% of swimmers failed to achieve a new PB in Rio). Of those that did set a new PB at the Rio games the magnitude of improvement was 1.6 ± 3.2% faster. Interestingly, a majority of medal winners (65%) achieved a new PB at the Olympic Games, highlighting the importance of being able to perform at their best, when at the highest level of competition.

A very interesting anomaly concerning the 50m freestyle event of the Rio swimming competition has recently been published by two sources (1, 11). The theory is that a current in the Olympic swimming pool affected swimmers times in specific lanes. The presented data demonstrated lanes 1 to 4 posted faster times compared to swimmers in lanes 5 to 8. The effect was limited to 50m events due to the directional current cancelling out when swimming in the opposite direction, which occurs in multiple lap races. Swimmers qualifying from semi-finals to the 50m freestyle final were disproportionally represented from lanes 1-4 (15 out of 16 swimmers). It is likely this anomaly may have influenced the overall positive RSPG% score of the 50m freestyle events, and potentially explains why the 50m freestyle event did not follow the trend that the longer the event distance the greater the PB success rate.

Not all athletes that medalled at Rio needed to produce a PB (35%), some might have just missed out on a PB with a performance extremely close to their PB. It may have also been that these athletes were so far ahead of their competition, that they were not pushed to their maximal performance level which matched competition brings (14), alternatively it may have just been luck that their competitors did not swim as well as they could have. Nevertheless, 81% of gold medal winners at the Rio 2016 Olympic Games achieved a PB to win their event. In comparison, Silver and bronze medallists, produced a PB relatively less often at 62% and 54%, respectively. Coaches and sports administrators interested in performance time prediction should analyse the leading competitors' times and build in the event specific range of RSPG.

Inter-country performance differences are very apparent. We assessed the same 24 nations that Issurin et al. (7) reviewed following the 2004 Olympic Games. Thereby allowing comparisons between the two Olympic campaigns, 12 years apart. At the 2016 Olympics the United States of America and Japan had the joint highest PB success rate (50%) with similar mean RSPG% scores of -0.3 ± 1.0% and -0.2 ± 1.3%, respectively. These nations overall slight declines in performance matches previous findings (7). In 2016, Croatia was the only nation to swim faster than their mean PB, with a positive RSPG% (0.1 ± 1.4%, n = 4) which contrasts with their 2004 Athens performance where Croatia had a mean performance decline (7). Overall, by nation athletes from all the other countries swam slower at Rio 2016 than their pre-Olympic PB.

The reason that overall most nations swam slower than their PB, could be explained by numerous external factors; but it does show the difficulty in correctly timing a swimmers peak. Maximizing performance in swimming relies on the interaction between psychology, fitness, and also in the optimization of training volume, intensity and recovery and minimizing illness and injury. From a physiological point of view a taper can bring possible haematological changes, respiratory exchange stability and reduction in hormonal stress markers such as cortisol (13). Psychologically, tapering may reduce total mood disturbances, improve somatic relaxation and improve quality of sleep (13). With these potential benefits of tapering in mind, any taper that is not effective can work against the athlete and these possible positives will be diminshed (9). Issurin et al. (7) noted that there are variations between nations and their final stage preparations for Olympic Games and shorter final stage preparations tended to strongly associate with higher peaking performances in swimming events. An effective taper can lead to a performance improvement of 3% (6) above their prior final stage performance level. We found that swimmers producing a PB in Rio had a mean improvement of

1.6% with a large standard deviation of 3.2% demonstrating that a small proportion of swimmers would have exceeded the 3% improvement level. Another point worthy of consideration is that Houmard and Johns (6) measured the improvement percentage from the pre-taper performance which may be a long way off an athlete's actual PB, especially after a long and fatiguing build-up. But tapering still requires a good understanding of the athlete involved in order to assess what overload level is required for that individual for it to be effective (13). Ultimately, differences in performance gains are explained in part by the differences in tapering regimes followed by each country (2). Knowing the background to a countries preparation strategy and matching this with our presented data will allow the determination of how successful a particular strategy was.

Research by Issurin et al. (7) with 301 swimmers (24 nations) at the Athens 2004 Olympic Games, showed 27.9% of the variance of RSPG% could be attributed to Olympic rank ($P < 0.01$). We found, that stroke-type, distance, age and Olympic rank greatly influence swimmers ability to achieve new PBs at Olympic Games ($P < 0.01$). These factors may be useful for sports administrators and coaches to consider in allocating their limited financial resources and implementing selection policy to maximise targeted success. While the current research describes factors external to swimmers, future endeavours should consider the physiological factors affecting RSPG%. Further modelling of performance and time predictions, which has already been explored to a certain degree (12) will allow coaches to better predict expected winning times in future games.

Conclusions

The ability to maximize performance on a particular day is a challenge to all athletes, coaches and scientists. Olympic athletes face the tougher challenge of having to truly peak once every 4 years; while for some swimmers getting selected for only one Olympics – this day will be targeted as a career peak. We quantified the likelihood of producing a PB time at the 2016 Rio Olympics and the magnitude of this improvement over a current PB. Our analysis revealed that less than third of all event entries produced a new PB at the Olympics. While of those that did manage to produce a PB, the mean improvement was swimming 1.6 ± 3.2% faster, and their Olympic PB came a mean of ~14 months after setting their previous PB. Furthermore, younger swimmers (≥ 19 years) were more than twice as likely to produce a PB as swimmers older than 25 years. Finally, we discovered with the exception of the 50m distance, there was a trend for an increased likelihood of setting a PB with races over an increased distance.

Practical Application

Combining our data with knowledge of actual preparation strategies employed by specific swimmers or teams allows the relative success of a said approach to be assessed. This information is beneficial for those making performance predictions and training programming decisions for future events. The research provides a greater insight of the levels of performance required to win an Olympic Games medal. Coaches can use this data to make informed decisions as to whether an athlete will reach the Olympic standard and consequently have a realistic opportunity of winning a medal.

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