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The importance of previous season performance on world-class 200- and 400-m individual medley swimming

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ABSTRACT: We examined the degree to which 200-m and 400-m Individual Medley (IM) performance was related to sprint-, middle- and long-distance events before a swimmer reached a Top-20 world ranking. A retrospective longitudinal modelling study was conducted. Data on Top-20 swimmers between 2010 and 2018 were obtained from publicly available websites. A general linear model was used to examine associations between 200-m and 400-mIM performance (FINA ranking points) and performance in sprint, middle-distance and distance events in the previous two years. In the 200-mIM, there were significant associations ($p < 0.001$) between prior competition results obtained for both the 200-mIM ($r = 0.80$; $\beta = 0.543$) and 400-m IM ($r = 0.70$; $\beta = 0.317$) events before the Top-20 performance in 200-mIM in the year of the Top-20. Sprint distance events were associated ($p < 0.006$; $r = 0.39$; $\beta = 0.088$) with 200-mIM (t). Each additional 10 FINA points in the 200-mIM in each of the two years preceding the Top-20 performance. were associated with an increase of 5 FINA points in 200-mIM in in the year of the Top-20 (goodness of fit $R^2 = 0.70$). There were similar associations ($p < 0.001$) for a Top 20-FINA 400-mIM performance with both 200-mIM ($r = 0.72$; $\beta = 0.385$) and 400-m IM ($r = 0.79$; $\beta = 0.492$) events in the two years before a swimmer reached the Top-20. Middle-distance events were associated with 400-mIM performance ($p < 0.001$; $r = 0.53$; $\beta = 0.163$). Each additional 10 FINA points in 400-mIM in in each of the two years preceding the Top-20 performance were associated with an increase of 5 FINA points in in the year that a swimmer reached the Top-20 (goodness of fit $R^2 = 0.75$). The specificity and complexity of the IM require a thorough preparation in this event for world-class performances. The 200-mIM is more closely related to sprint distance events, whereas middle-distance events support preparations for the 400-mIM.

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INTRODUCTION

Longitudinal progression between international competitions and/or seasons can be established by tracking the swimmers' performance for a given period of time, and analyzing their progression and consistency in performance [1–3]. There is a long-standing interest in the swimming community on the progression and consistency in the performance of successful and non-successful participants in the most important international events (Olympics, World-Championship), even swimming performance within and between competitions [4]. Allen et al. [5] conducted a similar methodology modelling the career performance trajectory of Olympic swimmers. Trajectories provided estimates of age of peak performance and the duration of the age window of improvement and decline around the peak. Yustres et al. [6] showed the annual performance progression from junior WC positively affects the chances of success at the senior WC. In this study world-class swimmers who were ranked in the Top-20 swimmers of the FINA achieved performance times that substantially increased their chance of an Olympic medal. Pyne et al. [2] showed that to stay in contention for a medal, an Olympic swimmer should improve his or her performance by around 1% within a competition and by around 1% within the year leading up to the Olympics. Costa et al. [3] conceptualized world-ranked swimmers (successful) as a top-150 world-ranked swimmer for long course during the 2007–2008 season, in any of the freestyle events presented in the Olympic calendar (the 50 m, 100 m, 200 m, 400 m and 1500 m events). König et al. [7] considered world class level swimmers (successful as finalists of events such as World Championships and Olympic Games. In our study successful swimmers as considered all world-class swimmers who were ranked in the Top-20 swimmers of the FINA. Also, in our case we narrowed the definition of successful swimmers as a Top-10 ranked swimmer who can improve performance time and be in contention for an Olympic medal [8].

The career of an successful swimmer typically involves a several years competing in the important junior and senior events, but few data exist for changes in performance across years [8]. It would appear logical to track the progression of swimmers who have been successful at a world class level to identify important elements of the pathway, and requirements of swimmers for the future.

In swimming, the optimal performance progression has been focused on annual progression [1–3, 8] or freestyle progression over several years [9]. However, there is a lack of knowledge of performance progressions in other strokes and IM events, and over a shorter time frame within an Olympic cycle (< 4 yr) that is the focus of most coaches and swimmers. The 200-mIM and 400-mIM events are the most challenging events in swimming, and require a complexity in their preparation that gives them a special appeal. The 200-mIM event helps swimmers to acquire a wide range of swimming strokes and skills, while the 400-mIM for swimmers over 12 years old is useful for developing endurance and maintaining the skills of the four strokes [10].

Swimming experts generally assert that it would take more time to achieve a high level of performance in the IM compared to freestyle [3, 11–14]. Moreover Vaso et al. [15] showed that the age in which swimmers achieve their best performance times for freestyle and IM are ~1–5 years younger for females (~22–25 years) than males. However, Dormehl et al. [16] observed that male IM swimmers peaked in performance earlier than the majority of other stroke specialists and showed the slowest rate of improvement from 12 to 19 years, implying they are often late developers. Smith [17] showed this process took years. Swimmers trained from an early age of (13–14) years resulting in the attainment of national team status by age around 17–18 years. Mastery and stabilization of training in subsequent years elicited Olympic medals in a quadrennial cycle.

The FINA points score system rates each individual race performance based on the current world record approved by FINA. The system permits comparisons of performances in different events, whereby more points (typically 1000 or more) are assigned to world-class performances and fewer points for slower performances [18]. However, there are no studies, to the best of our knowledge, which have systematic evaluated the patterns of improvements in 200-mIM and 400-m IM performance leading to international success. A key issue is the involvement of freestyle, other strokes, and performance over shorter (50-m to 200-m) and longer (800-m, 1500-m) distances. No previous study has systematically evaluated the influence of the so-called secondary events on subsequent performance, despite the widespread practice of swimmers competing in multiple events.

The aim of the study was to quantify associations between competition performances in the two years leading up to a Top 20 world ranking in the 200- and 400-m individual medley events. We also sought to characterise relationships between performance in other sprint, mid- and long-distance events, and 200-mIM and 400-mIM performance.

MATERIALS AND METHODS

Our own database was developed using historical data from websites for the official results. First, the Top-20 swimmers of the FINA World Ranking (Long Course) were selected from the website http://www.fina.org/ for 200-mIM and 400-mIM (male and female) from 2010 through 2018. Secondly, after selecting the swimmers, we searched the website http://www.swimrankings.net for the competitive performances (time) of each swimmer in the rankings for all individual events, including competitive events of 50, 100, 200, 400, 800, and 1500 m for any stroke that the swimmer completed included in the period from 2010 through 2018. The starting year 2010 was used to avoid the influence of polyurethane swimsuits on swimming performance. Two years before were defined based on the year 2010 as the second previous year.

The following explanatory variables were analyzed for statistical significance from the best results of 200-mIM to 400-mIM: age when swimmers reached the Top-20 position (the swimmers age based on date of birth and competition date at the time of the Top-20 performance), best FINA points of each Top-20 swimmers, FINA points two years before swimmer reached the Top-20 position in sprint (50–100 m), the middle-distance (200–400 m), and the long-distance (800 to 1500 m) events. Likewise, the best 400-m IM result of each swimmer in the year that they reached the Top 20, and the two previous years they occupied the Top-20 position, were considered as explanatory variables of the 200-mIM. The best time was considered for the 200-mIM in the previous results two years before. Similarly, the results for the 400-mIM were also collated. The final data comprised 8031 and 8033 entries in the 200-mIM and 400-mIM, respectively.

Descriptive statistics were used to examine the explanatory variables. A general linear model (GLM) was used to examine the association between the dependent variables 200-mIM and 400-mIM (one model for each) and the independent variables. For each model group (200-mIM and 400-mIM), specific models were developed for each sex. Coefficients R^2 were calculated as well as a global significance test to verify these models. The analysis was to determine whether the variables included in the models significantly influenced FINA points in the events 200-mIM and 400-mIM. The beta coefficients (β) show the degree of change in the outcome variable for every 1 unit of change in the predictor variable. Where the beta coefficient is positive, the interpretation is that for every 1 unit increase in the predictor variable, the outcome variable will increase by the beta coefficient value. Where the beta coefficient is negative, the interpretation is that for every 1 unit increase in the predictor variable, the outcome variable will decrease by the beta coefficient value. The increment for assess the response on other variables was established using a default value of 10 FINA points.

A p-value of less than 5% in the lineal regression model was considered significant. Model assumptions of normality and homoscedasticity were assessed using the Kolmogorov-Smirnov test and residuals graphics, respectively. In addition, together with the R2 as a measure of goodness of fit of the regression model and accuracy of the predictions, we calculated the Pearson's correlation coefficient of each of the explanatory variables on the objective or outcome variable (200-mIM and 400-mIM). We included these effect statistics given a p-value does not inform about the direction or size of the effect [19].All the residuals showed a satisfactory pattern. Statistical analyses were conducted using R software (v. 3.6.1 for Windows).

Ethics

The observational retrospective study was conducted in accordance with the Helsinki declaration. An ethical committee approved this research and since the data are based on publicly available resources, no informed consent was sought.

RESULTS

Results for 200 m IM swimmers.

Table 1 shows the results for FINA points in the 200-mIM best time based on the explanatory variables. The R-squared values were 0.70, 0.68 and 0.73 respectively for all IM swimmers, both females and males, indicating an acceptable degree of goodness in the adjustment and therefore a model with good explanatory power.

There was a strong relationship between prior competition results obtained two years before on 200-mIM ($r = 0.80$; $\beta = 0.543$) and 400-mIM ($r = 0.70$; $\beta = 0.317$) and the final performance in the year where they achieved the top 20 FINA in 200-mIM. In addition, a lower association ($r = 0.39$; $\beta = 0.088$) was also evident between sprint distance and Top-20. Positive associations ($p < 0.001$) were identified between 200-mIM FINA Points and sprint distance events ($r = 0.39$; $p = 0.002$), and 400-mIM ($r = 0.80$; $p < 0.001$). Substantial differences ($r = 0.70$; $p < 0.001$) were also evident for the 200-mIM in each of the two years preceding the Top-20 performance and 200-mIM.

For both male and female swimmers, each additional year in a swimmer's age was associated with a reduction in performance of 1.5 FINA points ($r = 0.32$; $p < 0.001$). For each additional 10 FINA points in sprint-distance events the 200-mIM in the year of the Top-20 performance was 1 FINA point higher. Also, each additional 10 FINA points in 400-mIM was associated with a 3 FINA points improvement in 200-mIM in the year of the Top-20 performance. Finally, for each additional 10 FINA points in 200-mIM in each of the two years preceding the Top-20 performance, there was an improvement of 5 FINA points in 200-mIM in the specific year which swimmers achieved a Top-20 position.

An analysis of the results by female swimmers indicated that one more year of age in a female or male swimmer decreased FINA points by 2 ($r = 0.29$; $p < 0.001$). There were positive associations between the FINA points in 200-mIM in in the year of the Top-20 performance and both sprint distance ($r = 0.36$; $p < 0.001$), and 400-mIM ($r = 0.72$; $p < 0.001$), as well as in the timepoints 200-mIM ($r = 0.79$; $p < 0.001$) in each of the two years preceding the Top-20 performance (Table 1). For each additional 10 FINA points in sprint-distance events there was an increase of 1 FINA point in 200-mIM in the year of the Top-20 performance. In addition, each additional 10 FINA points in the 400-mIM test was associated with an increase of 3 FINA points in 200-m IM in t. For each additional 10 FINA points in 200-mIM in each of the two years preceding the Top-20 performance, there was an increase of 6 FINA points in 200-mIM in in the year of the Top-20 performance.

Besides, the male results confirm that participation in IM contest and a progression performance two years before lead to achieve TOP 20 FINA in 200-mIM which is shown in β values of Table 1. Each additional 10 FINA points in sprint-distance events represented an additional 1 FINA point in 200-m IM in the year of the Top-20 performance ($r = 0.43$; $p < 0.001$) evidenced by the lower β value for males ($\beta = 0.123$). Every additional 10 FINA points in the 400-mIM ($r = 0.68$; $p < 0.001$) resulted in an increase of 2 FINA points in 200-m IM in the year of the Top-20 performance. Finally, each additional 10 FINA points in 200-mIM ($r = 0.80$; $p < 0.001$) in each of the two years preceding the Top-20 performance increased 6 FINA points for 200-m IM in the year of the Top-20 performance.

Results for 400 m IM swimmers.

The results for FINA points in 400-mIM are presented in Table 2, in a similar pattern to 200-mIM, the R-squared values were 0.75, 0.76 and 0.71 respectively. The GLM showed positive associations ($r = 0.72$; $p < 0.001$) between 400-m IM FINA points and personal best on 200-m IM. The greatest significant association ($r = 0.79$; $p < 0.001$) appeared in the timepoint 400-m IM in each of the two years preceding the Top-20 performance. Additionally, a significant association ($r = 0.51$; $p < 0.05$) was evident between middle distance performance and the 400 IM. As with 200-m IM, these results indicate that specific competition, as well as the specificity of training, improves IM according to the β values. There is a strong relationship between prior competition results obtained two years before on 400IM ($\beta = 0.49$) and 200IM ($\beta = 0.39$) and the final performance in the year where they achieved the top 20 FINA in 400 IM, and to a lesser extent in middle distance events ($\beta = 0{,}16$).

The GLM indicated that each additional year of age resulted in a decrease of 1 FINA point ($r = 0.34$; $p = 0.05$), and each additional 10 FINA points in sprint distance was associated with a decrease of 2 FINA points in 400-m IM ($r = 0.33$; $p < 0.001$). In addition, each additional 10 FINA points in MD increased 2 FINA points in 400-m IM in the year of the Top-20 performance. Each additional 10 FINA points in the 200-m IM event in each of the two

TABLE 1. General linear model for achieving Top-20 FINA points in 200 m IM. A positive β value indicates a likely improvement in performance whereas a negative value indicates a reduction in performance.

	GLOBAL					
	Estimate(β)	**Std.Error**	**t value**	**p-value**	**R^2**	**r-value**
(Intercept)	88.983	25.52	3.48	< 0.001		
Age	-1.48	0.46	-3.16	0.002		0.32
Sprint Distance	0.09	0.03	2.74	0.006		0.39
Middle Distance	0.02	0.04	0.40	0.699	0.701	0.49
Long Distance	-0.04	0.02	-1.70	0.089		0.31
400 IM	0.32	0.04	7.87	< 0.001		0.70
200 IM	0.54	0.04	12.44	< 0.001		0.80
				FEMALES		
(Intercept)	114.398	14.84	7.70	< 0.001		
Age	-1.55	0.26	-5.86	< 0.001		0.29
Sprint Distance	0.09	0.01	5.62	< 0.001	0.681	0.36
400 IM	0.25	0.01	12.45	< 0.001		0.72
200 IM	0.57	0.02	22.66	< 0.001		0.79
				MALES		
(Intercept)	95.279	14.96	6.36	< 0.001		
Age	-1.64	0.32	-5.05	< 0.001		0.34
Sprint Distance	0.12	0.01	6.87	< 0.001	0.730	0.43
400 IM	0.19	0.02	9.12	< 0.001		0.68
200 IM	0.62	0.02	22.01	< 0.001		0.80

Note: SD: Sprint Distance (50–100 m); MD: Middle distance (200–400); LD: Long distance (800–1500 m); 200 IM: The relation between the FINA points achieved in the two years preceding the Top-20 performance in 200m-IM and the FINA points in the specific year which swimmers achieved a TOP-20 position in 200-mIM; 400IM: The relation between the FINA points achieved in 400-mIM and the FINA points in 200-mIM.

years preceding the Top-20 performance elicited an extra 4 FINA points in the personal best in the 400-m IM. Finally, for each additional 10 FINA points in 400-m IM two years before the achievement a Top-20 performance resulted in an increase of 5 FINA points in 400-m IM personal best.

There is a positive association in female swimmers between the FINA points in 400-mIM in in the year of the Top-20 performance and the following events: sprint ($r = 0.29$; $p = 0.001$), middle distance ($r = 0.54$; $p = 0.006$), long distance ($r = 0.43$; $p = 0.005$) and 200-mIM ($r = .74$; $p < 0.001$), as well as in 400-mIM ($r = 0.74$; $p < 0.001$) in each of the two years preceding the Top-20 performance. However, only 200-m IM, as well as in 400-m IM are more important for achieving greater performance according to the β values. Any additional 10 FINA points in sprint distance, reduced 1 FINA points on 400-m IM in the year of the Top-20 performance. Also, 10 additional FINA points in middle distance events meant an increase of 2 FINA points in 400-m IM in the year of the Top-20 performance, and any additional 10 FINA points in long distance represented an increase of 1 FINA point in 400-m IM. Finally, 10 additional FINA points in the 200-m IM resulted in an increase of 4 FINA points in 400-m IM in the year of the Top-20 performance, and each additional 10 FINA points in 400-mIM in each of the two years preceding the Top-20 performance meant an increase of 4 FINA points for 400-mIM in the year of Top-20.

The male swimmers showed similar results to the females. According to the β values only 200-mIM ($r = 0.69$; $p < 0.001$) and 400-mIM ($r = 0.80$; $p < 0.001$) two years before the Top-20 performance are the most relevant for achieving Top positions. For each additional 10 FINA points in middle distance ($r = 0.51$; $p = 0.05$), 2 FINA points were increased by 400-mIM in the year of the Top-20 performance. Also, 10 additional FINA points in the 200-mIM two years before the Top-20 performance, showed an increase of 4 FINA points in 400-mIM, and each additional 10 FINA points in 400-mIM two years before the Top-20 performance increased 4 FINA points for 400-mIM in the year of the Top-20 performance.

TABLE 2. General linear model for achieving Top-20 FINA points in 400 m IM. A positive β value indicates a likely improvement in performance whereas a negative value indicates a reduction in performance.

			GLOBAL			
	Estimate(β)	**Std.Error**	**t value**	**p-value**	**R^2**	**r-value**
(Intercept)	43.596	24.86	1.75	0.080.		
Age	-0.95	0.48	-1.94	0.05		0.34
Sprint Distance	-0.13	0.02	-4.80	< 0.001		0.33
Middle Distance	0.16	0.04	3.61	< 0.001	0.752	0.53
Long Distance	0.06	0.02	2.23	0.026		0.38
400 IM	0.49	0.04	11.94	< 0.001		0.79
200 IM	0.39	0.04	8.97	< 0.001		0.72
			FEMALES			
(Intercept)	47.199	30.54	1.54	0.123		
Age	-0.46	0.564	-0.81	0.414		0.35
Sprint Distance	-0.12	0.037	-3.26	0.001		0.29
Middle Distance	0.15	0.055	2.74	0.006	0.766	0.54
Long Distance	0.08	0.030	2.79	0.005		0.43
400 IM	0.44	0.049	8.86	< 0.001		0.78
200 IM	0.40	0.049	7.94	< 0.001		0.74
			MALES			
(Intercept)	42.770	47.62	0.89	0.371		
Age	-1.54	1.07	-1.42	0.157		0.30
Sprint Distance	-0.15	0.04	-3.26	0.001		0.36
Middle Distance	0.17	0.08	1.95	0.05	0.710	0.51
Long Distance	0.01	0.04	0.29	0.767		0.31
400 IM	0.57	0.07	7.43	< 0.001		0.80
200 IM	0.38	0.08	4.38	< 0.001		0.69

Note: SD: Sprint Distance (50–100 m); MD: Middle distance (200–400); LD: Long distance (800–1500 m); 400IM: The relation between the FINA points achieved in the two years preceding the Top-20 performance in 400m-IM and the FINA points in the specific year which swimmers achieved a TOP-20 position in 400-mIM; 200IM: The relation between the FINA points achieved in 200-mIM and the FINA points in 400-mIM.

DISCUSSION

This is the first study to analyse the pattern of associations and progression in competition performances of world class IM swimmers in both 200 and 400 IM and support events across a range of distances. The major outcome of this study is that results in both the speciality events (200-mIM and 400-mIM) and support or supplementary events in the two years before the year when swimmers earned the highest FINA points, were associated with an increase of FINA points. The challenge for coaches is two-fold: to balance the proportions of medley, freestyle and form stroke training across a range of distances, and make strategic decisions on the choice of events in major and minor competitions. This challenge and its complexity give the IM special appeal for coaches, swimmers and the broader swimming community. In this sense, the preparation for both the 200 and 400 IM involving the combination of all four strokes creates unique energetic requirements [20] and a suitable balance in training strong and weak strokes is required. An effective pacing strategy is also necessary given that improvements in specific lap times are associated with substantial improvements in final time for 100- to 400-m swimming events [21]

Our results confirm three different IM swimmers profiles: 200-mIM holding higher FINA points in sprint swimming (e.g. Alicia Coutts AUS [6 years in Top-20 with 200-mIM and 6 sprint events ranging between 750–1000 FINA points], or Ryan Lochte USA [8 years in Top-20 and 5 sprint events ranging between 750–1000 FINA points]), 200–400-mIM swimmers (e.g. Kosuke Hagino JPN [8 years in Top-20 and 2 IM events ranged between 951–1000 FINA points], and Katinka Hosszú HUN who is the current world record holder in

200-mIM and 400-mIM [9 years in Top-20 and 2 IM events ranged between 951–1000 FINA points]), and 400-mIM specialists holding higher FINA points in middle distance (Mireia Belmonte ESP [9 years in Top-20 and 5 middle distance events ranged between 750–1000 FINA points] and David Verratszo HUN [9 years in Top-20 and 5 middle distance and 2 long distance events ranged between 750–1000 FINA points]).

The importance of progressions in training and competition performance has been analysed for important international events. Pyne et al. [2] reported an improvement of approximately 1.0–1.4% in performance time is needed the year preceding an Olympics. By tracking the progression of swimmers who had been successful during previous seasons, we identified the critical elements of the pathway and requirements of swimmers for the future achievements. Emerging swimmers should train and compete in both the 200-mIM and 400-mIM given their close association and transfer in competition performances, and that performance achieved in junior categories predict ~60% of the performance in senior categories [6].

Swimmers are more consistent between distances with the same stroke than between strokes with the same distance [4]. Hence, coaches and swimmers should consider the value of training and competing in range of events across strokes (freestyle, form stroke, medley) and distances (100 to 800-m) to improve the consistency between strokes for IM swimmers. Specifically, the performance in sprint distance events is a determinant factor for 200-mIM (more prominent in men than women). Similar results are shown for 400-mIM between genders, but the positive associations to performance in other events are linked to middle distance events consistent with the three different IM swimmer profiles.

Our results also show a positive relationship in performance between the 200-mIM and 400-mIM events. Swimming fast in sprint distance events in all strokes, as well as 200m is crucial to a fast 200-mIM. A positive influence in performance progression was identified between IM events and other swimming events. This outcome is consistent with the results of Buhl et al. [22] showing males and females improved swim speeds in the freestyle and individual medley in the 200 m and the 400 m over the years, but this study was limited only to Swiss swimmers. Collectively our results, and those of Buhl et al. [19], reinforce the specificity and complexity of IM training, and the importance of a balance of sprint training across all strokes, form stroke (interval) training in backstroke, breaststroke and butterfly, and pacing specific to both the 200- and 400-IM events.

In the 400-mIM, different swimming events (mid- and long-distance) were associated positively with the final performance although associations were sex-specific. A negative association with sprint events were found with 400-m IM, which supports the statement of Sweetenham and Atkinson [10] who recommended increase efficiency and minimising resistance rather than solely pursuing speed. In males, sprint events negatively influenced the personal best in the 400-mIM, whereas mid-distance events positively affected the final performance in the 400-mIM. According to our results, to achieve better times in the 400-m competition, males should improve their time in the 200-m event, especially the backstroke [23] and the 400-m freestyle and, to a lesser extent, the 800- and 1500-m freestyle.

In female swimmers, middle-distance events had more influence on the final performance in the 400-mIM. Long-distance events had less benefit for 400-mIM (than in males), and similar to the men there was a negative association with sprint events. In contrast to male swimmers, the females should focus on achieving better results in the 400-m IM, and middle-distance events of each stroke individually. These outcomes can be used by swimming coaches to design and implement peaking strategies for the key competitions in the annual plan, coaches should include early competitions in middle-distance events as strategy of preparation for 400-m.

In terms of the age at which swimmers reach their best performance Allen et al. [5] indicated that the mean age of peak performance in top swimmers of ~24 years for men and ~22 years for women. Nevertheless, our results showed that swimmer age negatively influenced both sexes in the performance of the medley event, since male swimmers were typically 21 and females 19 years old. Vaso et al. [15] reported that the age of peak swim times appeared 1–3 years earlier for females (20–21 years) than for males (22–23 years) in the 200-mIM and 400-mIM. These results are in line with the longitudinal study of Donato et al. [24] showing that performance of female swimmers declines more in sprint events than in endurance. Ransdell et al. [25] reported that women's performances did not decline as substantially as men's, especially in middle-distance and long-distance events. Age as an indicator of peak performance is limited given the involvement of other factors including the length of time the athlete has been competing, experience, genetics, physiological and psychological adaptations which have not been considered in this study.

CONCLUSIONS

There is a substantial relationship in performance between the 200-mIM and 400-mIM events. It appears that success in medley swimming in the two years before attaining a FINA Top-20 performance has a substantial positive effect on performance in world-class 200-mIM and 400-mIM swimmers. Sprint-distance events in each stroke individually for both sexes showed a strong relationship with the final performance in 200-mIM. With regard to the 400-mIM event, the personal best in 200-mIM for form strokes (non-freestyle strokes) was strongly related to 400-mIM performance for males. In female swimmers, performance in 400-mIM was related more to the personal best in 200-m events of each stroke and 400-mIM. Coaches should consider the relative contributions of form strokes in shorter distance (for the 200-IM), as well as medley swimming, to best prepare for the 200-mIM and 400-mIM events.

Contributorship Statement

All authors contributed appropriately to the design, planning, execution and writing of this paper.

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