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Normative data of the start in the 50 m events at the 2021 LEN European Championships and understanding its relationship with the final race

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Abstract: This study aimed to: (i) present normative data of the variables related to the start in the four swim strokes by tier and sex, and; (ii) understand the relationship between the 15th meter mark time and the final race time of the male and female swimmers competing in the four 50 m events at the 2021 European Championships. Participants were all male and female swimmers who competed in the 50 m events at the 2021 LEN European Championships held in Budapest. The official race times and block times were retrieved from the official competition website. All starting variables were analyzed in a dedicated software for race analysis. The 15th meter mark time was used as the start main outcome. For all events by sex, the 15th meter mark time was the variable presenting the highest and largest tier effect ($p < 0.001$) besides the final race time. Overall, despite the swim stroke, the variables related to the underwater phase were also responsible for the significant tier effect ($p < 0.001$). The 15th meter mark time presented a high to very-high relationship with the final race time in all four swim strokes. This relationship was stronger in freestyle (both sexes). That is, swimmers who achieve the 15th meter mark sooner are more likely to deliver better performances. Coaches must be aware that the underwater phase plays a key-role on the swimmers' (both sexes) start performance. Nonetheless, different strategies can be used based on the swimmers' strength and weaknesses. Moreover, the start performance in all four swim strokes and in both sexes can strongly predict the final race time.

Keywords: analysis; biomechanics; performance; race strategy

1. Introduction

Race analysis in swimming plays a determinant role in the athletes' performance enhancement (Born et al., 2022; Morais et al., 2022a). Coaches and swimmers can receive plenty of information about their race performance. Overall, such information can be related to the start, clean swim, turn(s), and finish (Born et al., 2021; Simbaña-Escobar et al., 2018; Veiga & Roig, 2017). However, as the race distance becomes shorter, this amount of information also diminishes. This occurs mainly in short-distance events more specifically in the 50 m events. Therefore, as swimmers spent less time racing, every detail they can receive could play a substantial role on their performance. The 50 m events in long-course meter swimming pools (Olympic races in pools with 50 m of length), at least for males, are considered an all-out race (Morais et al., 2022a; Oliveira et al., 2022). Until recently, it was quite hard to understand the swimmers' race profile in such events. This occurred because swimmers only performed one lap. Thus, research groups that have a focus on race analysis, started to divide the swimming pool into sections (Morais et al., 2022a; Simbaña et al., 2018; Arellano et al., 2018). This approach allowed to better understand the swimmers' profile during the race. Overall, the 50 m events can be divided into the start (15 m mark time), clean swim (between the 15th and the 45th meter), and the finish (last 5 m of the race) (Morais et al., 2022a). At least in male elite 50 m freestyle swimmers, it was noted that they tended to decrease their swimming speed along all race sections (all-out race) (Morais et al., 2022a,b). In the specific case of the start, it was noted that this section plays a key-role on the swimmers' final race time (Morais et al., 2019). That is, swimmers who can achieve the 15th meter mark faster are more likely to deliver a better performance. Studies have shown the main determinants for achieving a faster start (Garcia-Ramos et al., 2015; Peterson et al., 2018; Tor et al., 2015). Overall, swimmers presented a faster start based on a faster take-off horizontal velocity and a better hydrodynamic profile (underwater phase of the start). It seems that displacing through an "ideal" underwater trajectory will allow swimmers to reduce the water resistance, maintaining a faster underwater speed and consequently a faster start (Tor et al., 2015). However, there is scarce evidence about the relationship between the start and the race time in a real competition context. A study by Marinho and co-workers (2021) noted that the 15th meter mark time presented a significant and positive correlation with the final race time in male elite 50 m freestyle sprinters. That is, swimmers who take more time to achieve the 15th meter mark are more likely to take more time finishing the race. Others, focused on providing normative data (percentiles) about the contribution of the 15th meter mark time to the final race time in all four swim strokes in elite male 50 m sprinters (Born et al., 2021). The authors noted that, in all percentiles, the contribution of the 15th m mark time to the final race time in all four swim strokes ranged between 23% and 27% depending on the swim stroke. This highlights the importance of the start on the final race time in sprinting events. Moreover, as far as our understanding goes, only one study analyzed this kind of relationships in female swimmers (Arellano et al., 2022). Thus, it seems that literature lacks information about this race analysis topic in female swimmers. Therefore, this study aimed to: (i) present normative data of the variables related to the start in the four swim strokes by tier and sex, and; (ii) understand the relationship between the 15th meter mark time and the final race time of the male and female swimmers competing in the four 50 m events at the 2021 European Championships. It was hypothesized that: (i) in all four swim strokes (both sexes) it would be possible to split swimmers by tiers with significant differences between them, and; (ii) the final race time of both sexes can be predicted by the 15th meter mark time with a high to very-high relationship in the four swim strokes.

2. Materials and Methods

Subjects — Participants were all male (backstroke: 78 swimmers; breaststroke: 79 swimmers; butterfly: 89 swimmers; freestyle: 95 swimmers) and female (backstroke: 78 swimmers; breaststroke: 75 swimmers; butterfly: 74 swimmers; freestyle: 86 swimmers) swimmers who competed in the 50 m events at the 2021 LEN European Championships held in Budapest. Only swimmers with final times were analyzed (i.e., disqualifications were not considered). For males, the 50 m backstroke performance reached 93.51±3.09% the World Record, the 50 m breaststroke 93.59±3.04%, the 50 m butterfly 93.24±2.81%, and the 50 m freestyle 92.39±3.56%. For females, the 50 m backstroke performance reached 94.12±3.12% the World Record, the 50 m breaststroke 93.65±2.73%, the 50 m butterfly 91.79±2.95%, and the 50 m freestyle 93.84±2.68%. All procedures were in accordance with the Declaration of Helsinki regarding human research, and the Polytechnic Ethics Board approved the research design (N. º 73/2022). The investigation was performed according to international standards and as required by Harriss et al. (2019).

Methodology — The official race times and block times were retrieved from the official competition website (http://budapest2020.microplustiming.com/indexBudapest2021_web.php). All video clips were provided in high-definition video (*f*=50Hz) based on a 10 pan-tilt-zoom camera setup. Each swimmer was recorded by one camera (i.e., one camera per lane) allowing the analysis of the start individually. Pool calibration was set before every session. The start strobe lights were synchronized with the official timing system and were visible by all cameras and it was used as a reference to set the timestamp on the race analysis software (Morais et al., 2019). Two expert race analysts performed each race analysis. The agreement between both analysts was assessed with the Intraclass Correlation Coefficient (ICC). This revealed a very-high agreement (ICC = 0.998).

The following variables were used as start determinants: (i) 15th meter mark time (i.e., start main outcome: the time lag between the starting signal and the 15th m mark); (ii) reaction time or block time (the time lag between the signal and the instant the swimmer's feet left the block – retrieved from the championship official website: http://budapest2020.microplustiming.com/indexBudapest2021_web.php); (iii) entry time (the time lag between the start signal and the hands' water contact time); (iv) flight time (the time lag between the instant the toes left the block and the hands' entry); (v) entry distance (the distance between the starting head-wall and the hands' entry); (vi) underwater time (the time lag between the hand's entry and the water break by the head); (vii) underwater distance (the distance between the hand's entry and the water break by the head); (viii) underwater speed (speed correspondent to the underwater distance); (ix) water break time (the time lag between the start signal and the head breaking out the water surface), and; (x) water break distance (the distance between the starting head-wall and the head water breakout) (Morais et al., 2019).

Statistical Analysis — The Kolmogorov-Smirnov and the Levene tests were used to assess the normality and homoscedasticity, respectively. The mean plus one standard deviation were computed as descriptive statistics. For each race event, by sex, the dataset was split into three tiers: (i) tier #1 – best performers; (ii) tier #2 – intermedium performers, and; (iii) tier #3 – poorest performers. This was done based on the percentile value of three equal groups having as reference the final race time.

The one-way ANOVA ($p < 0.05$) was used to verify the tier effect in each swim stroke by sex. The effect size index (eta square – η^2) was computed and interpreted as: (i) without effect if $0 < \eta^2 \leq 0.04$; (ii) minimum if $0.04 < \eta^2 \leq 0.25$; (iii) moderate if $0.25 < \eta^2 \leq 0.64$ and; (iv) strong if $\eta^2 > 0.64$ (Ferguson, 2009). Bonferroni post-hoc correction ($p < 0.05$) were used to verify significant differences between tiers.

Linear regression was used to understand the relationship between the final race time (dependent variables) and the 15th m mark time (independent variable). The relationship was defined as: very weak if $R^2 < 0.04$; weak if $0.04 \leq R^2 < 0.16$; moderate if $0.16 \leq R^2 < 0.49$; high if $0.49 \leq R^2$ 0.81 and; very high if $0.81 \leq R^2 < 1.0$ (Barbosa et al., 2018).

3. Results

Table 1 presents male swimmers' descriptive data of the four swim strokes by tier and the tier effect. In all four swimming strokes, the race time was the variable presenting the highest and largest tier effect ($p < 0.001$). Besides the race time, the 15th meter mark time was the variable presenting the highest and largest tier effect where the fastest swimmers (tier #1) were also the ones achieving this mark sooner (backstroke: $F = 20.853$, $p < 0.001$, $\eta^2 = 0.36$; breaststroke: $F = 20.281$, $p < 0.001$, $\eta^2 = 0.35$; butterfly: $F = 35.355$, $p < 0.001$, $\eta^2 = 0.45$; freestyle: $F = 59.362$, $p < 0.001$, $\eta^2 = 0.56$). Overall, backstrokers in tier #1 (best performers) presented fastest times and speeds, as well as longer distances. The variables related to the underwater phase (i.e., underwater distance and speed) and water break distance were also the ones with a significant tier effect ($p < 0.001$). As for breaststroke, the entry distance also presented a significant tier effect ($F = 6.189$, $p = 0.003$, $\eta^2 = 0.14$), where based on descriptive data swimmers in tier #1 presented longer entry distance, followed by swimmers in tier #2 and #3. In butterfly, variables related to the underwater phase (specifically, the underwater distance and speed) were also the ones presenting a significant tier effect ($p = 0.002$ and $p = 0.001$, respectively). Swimmers in tier #2 where the ones presenting the longest underwater distance and fastest underwater speed, followed by swimmers in tier #1 and #3. As in freestyle, the entry time, underwater distance, underwater speed, and water break time also presented a significant tier effect. Overall, freestylers in tier #1 presented the longest distances and fastest times or speeds.

Table 2 presents female swimmers' descriptive data of the four swim strokes by tier and the tier effect. In all four swimming strokes, as in their males' counterparts, the race time was the variable presenting the highest and largest tier effect ($p < 0.001$). Again, as for males, the 15th meter mark time was the variable presenting the highest and largest tier effect besides the race time (backstroke: $F = 43.911$, $p < 0.001$, $\eta^2 = 0.54$; breaststroke: $F = 42.559$, $p < 0.001$, $\eta^2 = 0.54$; butterfly: $F = 74.532$, $p < 0.001$, $\eta^2 = 0.68$; freestyle: $F = 66.725$, $p < 0.001$, $\eta^2 = 0.62$). Female backstrokers in tier #1 and #2 reacted faster than those in tier #3. Swimmers in tier #1 also presented longer distances and a faster underwater speed. Breaststrokers in tier #1 reacted faster and presented a faster underwater speed than their tier #2 and #3 counterparts. As for butterfly, swimmers in tier #1 spent more time underwater allowing them to cover a larger underwater distance, and a water break distance. Freestylers in tier #1 were faster in the reaction/block time than their tier #2 and #3 counterparts and presented a longer entry distance. They also presented a faster underwater speed and a longer water break distance.

Figure 1 depicts the standardized linear regression between the race time and the 15th meter mark time in all four swim strokes by sex. For males, the freestyle stroke (R^2 = 82.0%, $p < 0.001$) was the one presenting the highest and strongest relationship between the race time and the 15th meter mark time (panel A4). It was followed by the butterfly (panel A3: R^2 = 74.7%, $p < 0.001$), breaststroke (panel A2: R^2 = 46.9%, $p < 0.001$), and backstroke (panel A1: R^2 = 36.7%, $p < 0.001$), respectively. As for females, the freestyle stroke was also the one presenting the highest and strongest relationship between the race time and the 15th meter mark time (panel B4: R^2 = 86.0%, $p < 0.001$). Afterwards, it was the butterfly stroke (panel B3: R^2 = 74.6%, $p < 0.001$), backstroke (panel B1: R^2 = 65.6%, $p < 0.001$), and breaststroke (panel B2: R^2 = 58.0%, $p < 0.001$).

Table 1. Males' descriptive data (mean ± one standard deviation – 1SD) by tier and level effect.

	backstroke				
	Tier #1 Mean±1SD	**Tier #2 Mean±1SD**	**Tier #3 Mean±1SD**	**F-ratio (p)**	**η^2**
Race time [s][a]	24.67±0.33	25.31±0.15	26.43±0.76	86.136 (<0.001)	0.70
15 m time [s][b]	6.12±0.15	6.22±0.23	6.62±0.43	20.853 (<0.001)	0.36
Block time [s]	0.58±0.05	0.58±0.04	0.59±0.05	0.737 (0.482)	0.02
Entry time [s]	0.69±0.05	0.69±0.06	0.69±0.05	0.001 (0.999)	0.00
Flight time [s]	0.11±0.06	0.11±0.06	0.10±0.06	0.461 (0.633)	0.01
Entry distance [m]	2.62±0.14	2.52±0.23	2.51±0.20	2.355 (0.102)	0.06
Underwater time [s]	4.94±0.32	5.00±0.29	4.77±0.65	2.023 (0.139)	0.05
Underwater distance [m][b]	11.27±0.93	11.32±1.02	10.01.64	9.432 (<0.001)	0.20
Underwater speed [m/s][b]	2.28±0.08	2.26±0.12	2.11±0.27	7.512 (0.001)	0.17
Water break time [s]	5.64±0.31	5.70±0.27	5.46±0.64	2.120 (0.127)	0.05
Water break distance [m][b]	13.89±0.91	13.84±0.92	12.52±1.64	10.823 (<0.001)	0.22
	breaststroke				
	Tier #1 Mean±1SD	**Tier #2 Mean±1SD**	**Tier #3 Mean±1SD**	**F-ratio (p)**	**η^2**
Race time [s][a]	26.91±0.34	27.66±0.22	28.71±0.98	57.230 (<0.001)	0.60
15 m time [s][a]	6.31±0.20	6.49±0.23	6.74±0.30	20.281 (<0.001)	0.35
Block time [s]	0.66±0.34	0.66±0.32	0.66±0.04	0.128 (0.880)	0.00
Entry time [s]	1.00±0.35	0.99±0.50	1.00±0.05	0.577 (0.564)	0.02
Flight time [s]	0.35±0.05	0.33±0.50	0.34±0.06	0.406 (0.667)	0.01
Entry distance [m][d]	3.68±0.20	3.52±0.18	3.49±0.22	6.189 (0.003)	0.14
Underwater time [s]	4.58±0.43	4.79±0.52	4.70±0.47	1.313 (0.275)	0.03
Underwater distance [m]	9.09±1.46	9.43±1.77	9.19±1.31	0.356 (0.702)	0.01
Underwater speed [m/s]	1.98±0.19	1.96±0.20	1.95±0.14	0.209 (0.812)	0.01
Water break time [s]	5.58±0.44	5.78±0.53	5.70±0.45	1.153 (0.321)	0.03
Water break distance [m]	12.77±1.50	12.96±1.78	12.68±1.37	0.220 (0.803)	0.01
	butterfly				
	Tier #1 Mean±1SD	**Tier #2 Mean±1SD**	**Tier #3 Mean±1SD**	**F-ratio (p)**	**η^2**
Race time [s][a]	23.27±0.17	23.71±0.19	24.71±0.76	75.207 (<0.001)	0.64
15 m time [s][b]	5.44±0.16	5.55±0.14	5.91±0.33	35.355 (<0.001)	0.45
Block time [s]	0.63±0.05	0.64±0.04	0.65±0.04	1.655 (0.197)	0.04
Entry time [s]	0.98±0.03	0.98±0.06	0.99±0.04	0.554 (0.577)	0.01
Flight time [s]	0.37±0.13	0.34±0.52	0.33±0.05	1.718 (0.185)	0.04
Entry distance [m]	3.58±0.24	3.49±0.26	3.47±0.26	1.337 (0.268)	0.03
Underwater time [s]	3.41±0.52	3.70±0.67	3.74±0.72	2.347 (0.102)	0.05
Underwater distance [m][e]	8.34±1.62	9.65±1.18	8.28±1.90	6.972 (0.002)	0.14
Underwater speed [m/s][f]	2.45±0.39	2.70±0.71	2.22±0.27	7.079 (0.001)	0.14
Water break time [s]	4.39±0.50	4.68±0.65	4.73±0.72	2.429 (0.094)	0.05
Water break distance [m][e]	11.92±1.59	13.14±1.08	11.76±1.88	7.036 (0.001)	0.14
	freestyle				
	Tier #1 Mean±1SD	**Tier #2 Mean±1SD**	**Tier #3 Mean±1SD**	**F-ratio (p)**	**η^2**
Race time [s][a]	21.90±0.15	22.39±0.20	23.69±0.89	95.073 (<0.001)	0.67
15 m time [s][a]	5.44±0.12	5.56±0.16	5.95±0.27	59.362 (<0.001)	0.56
Block time [s]	0.64±0.04	0.64±0.03	0.64±0.05	0.154 (0.858)	0.00
Entry time [s]	0.97±0.04	0.97±0.03	0.97±0.05	0.042 (0.959)	0.00

Flight time [s]	0.34±0.05	0.33±0.04	0.33±0.06	0.218 (0.805)	0.01
Entry distance [m][a]	3.69±0.19	3.55±0.20	3.40±0.23	15.206 (<0.001)	0.25
Underwater time [s][c]	2.65±0.70	3.00±0.55	3.06±0.50	4.407 (0.015)	0.09
Underwater distance [m][c]	6.49±1.61	7.32±1.62	7.45±1.29	3.663 (0.029)	0.07
Underwater speed [m/s]	2.48±0.26	2.45±0.40	2.45±0.27	0.101 (0.904)	0.00
Water break time [s][c]	3.63±0.70	3.98±0.54	4.03±0.52	4.315 (0.016)	0.09
Water break distance [m]	10.18±1.58	10.86±1.64	10.85±1.33	2.063 (0.133)	0.05

p – significance value; η^2 – eta square (effect size indicator); a – significant differences ($p < 0.05$) between the three tiers; b – significant differences ($p < 0.05$) between tier #1 and tier #3, and tier #2 and tier #3; c – significant differences ($p < 0.05$) between tier #1 and tier #3; d – significant differences ($p < 0.05$) between tier #1 and tier #2, and tier #1 and tier #3; e – significant differences ($p < 0.05$) between tier #2 and tier #1, and tier #2 and tier #3; f – significant differences ($p < 0.05$) between tier #2 and tier #3.

Table 2. Females' descriptive data (mean ± one standard deviation – 1SD) by tier and level effect.

			backstroke		
	Tier #1 Mean±1SD	**Tier #2 Mean±1SD**	**Tier #3 Mean±1SD**	**F-ratio (p)**	**η^2**
Race time [s][a]	27.79±0.28	28.47±0.22	29.84±0.80	110.203 (<0.001)	0.75
15 m time [s][a]	6.93±0.27	7.17±0.31	7.75±0.38	43.991 (<0.001)	0.54
Block time [s][b]	0.58±0.46	0.58±0.44	0.63±0.04	10.424 (<0.001)	0.22
Entry time [s][c]	0.68±0.06	0.68±0.05	0.72±0.05	4.165 (0.019)	0.10
Flight time [s]	0.10±0.05	0.10±0.04	0.09±0.05	0.558 (0.575)	0.02
Entry distance [m][c]	2.45±0.19	2.33±0.15	2.27±0.16	5.961(0.004)	0.14
Underwater time [s]	5.85±0.35	5.83±0.53	5.50±0.60	3.824 (0.026)	0.09
Underwater distance [m][b]	11.85±0.51	11.46±1.27	10.31±1.34	13.544 (<0.001)	0.27
Underwater speed [m/s][a]	2.03±0.10	1.96±0.07	1.87±0.13	15.809 (<0.001)	0.30
Water break time [s]	6.53±0.37	6.52±0.52	6.22±0.61	3.015 (<0.001)	0.07
Water break distance [m][b]	14.28±0.52	13.79±1.23	12.58±1.36	16.337 (<0.001)	0.30
			breaststroke		
	Tier #1 Mean±1SD	**Tier #2 Mean±1SD**	**Tier #3 Mean±1SD**	**F-ratio (p)**	**η^2**
Race time [s][a]	30.34±0.41	31.24±0.30	32.36±0.48	158.614 (<0.001)	0.82
15 m time [s][b]	7.46±0.19	7.58±0.21	7.99±0.24	42.559 (<0.001)	0.54
Block time [s]	0.68±0.03	0.68±0.04	0.70±0.04	3.710 (0.029)	0.09
Entry time [s]	0.98±0.06	0.96±0.06	0.97±0.05	0.550 (0.579)	0.02
Flight time [s]	0.30±0.05	0.27±0.08	0.27±0.06	1.777 (0.177)	0.05
Entry distance [m]	3.05±0.21	2.99±0.23	2.91±0.24	2.329 (0.105)	0.06
Underwater time [s][c]	4.43±0.33	4.63±0.41	4.80±0.64	3.761 (0.028)	0.10
Underwater distance [m]	9.26±0.79	9.66±0.98	9.24±1.27	1.280 (0.284)	0.03
Underwater speed [m/s][b]	2.10±0.15	2.09±0.13	1.93±0.11	13.000 (<0.001)	0.27
Water break time [s][c]	5.41±0.37	5.59±0.42	5.77±0.66	3.419 (0.038)	0.09
Water break distance [m]	12.31±0.82	12.64±1.00	12.14±1.29	1.461 (0.239)	0.04
			butterfly		
	Tier #1 Mean±1SD	**Tier #2 Mean±1SD**	**Tier #3 Mean±1SD**	**F-ratio (p)**	**η^2**
Race time [s][a]	25.79±0.23	26.51±0.19	27.67±0.72	111.472 (<0.001)	0.76
15 m time [s][a]	6.14±0.13	6.46±0.16	6.81±0.26	74.532 (<0.001)	0.68
Block time [s]	0.67±0.04	0.67±0.04	0.67±0.46	1.201 (0.307)	0.03
Entry time [s]	0.94±0.04	0.94±0.06	0.96±0.06	0.777 (0.464)	0.02
Flight time [s]	0.28±0.05	0.27±0.06	0.27±0.06	0.034 (0.966)	0.00

Entry distance [m][c]	3.04±0.15	2.99±0.26	2.88±0.23	3.384 (0.039)	0.09
Underwater time [s][c]	4.81±0.34	4.50±0.73	4.37±0.67	3.448 (0.037)	0.09
Underwater distance [m][d]	11.33±0.59	10.22±1.61	10.10±1.11	8.250 (0.001)	0.19
Underwater speed [m/s]	2.36±0.08	2.27±0.15	2.33±0.22	1.763 (0.179)	0.05
Water break time [s][c]	5.76±0.36	5.44±0.70	5.34±0.68	3.293 (0.043)	0.09
Water break distance [m][d]	14.38±0.56	13.21±1.47	12.98±1.16	10.905 (<0.001)	0.24
			freestyle		
	Tier #1 Mean±1SD	**Tier #2 Mean±1SD**	**Tier #3 Mean±1SD**	**F-ratio (p)**	**η^2**
Race time [s][a]	24.51±0.27	25.32±0.26	26.75±1.09	84.995 (<0.001)	0.67
15 m time [s][a]	6.13±0.15	6.47±0.15	6.85±0.36	66.725 (<0.001)	0.62
Block time [s][c]	0.66±0.03	0.67±0.04	0.69±0.06	4.130 (0.020)	0.09
Entry time [s]	0.96±0.05	0.95±0.06	0.97±0.06	1.347 (0.266)	0.03
Flight time [s]	0.30±0.05	0.29±0.07	0.28±0.07	0.852 (0.430)	0.02
Entry distance [m][c]	3.19±0.21	3.04±0.20	2.90±0.26	11.607 (<0.001)	0.22
Underwater time [s]	3.82±0.61	3.52±0.66	3.42±0.82	2.559 (0.084)	0.06
Underwater distance [m][d]	9.34±1.37	8.27±1.40	7.59±1.76	9.672 (<0.001)	0.19
Underwater speed [m/s][c]	2.46±0.34	2.37±0.23	2.23±0.17	5.972 (0.004)	0.13
Water break time [s]	4.79±0.62	4.47±0.67	4.40±0.80	2.516 (0.087)	0.06
Water break distance [m][d]	12.53±1.32	11.31±1.43	10.49±1.69	13.562 (<0.001)	0.25

p – significance value; η^2 – eta square (effect size indicator); a – significant differences ($p < 0.05$) between the three tiers; b – significant differences ($p < 0.05$) between tier #1 and tier #3, and tier #2 and tier #3; c – significant differences ($p < 0.05$) between tier #1 and tier #3; d – significant differences ($p < 0.05$) between tier #1 and tier #2, and tier #1 and tier #3; e – significant differences ($p < 0.05$) between tier #2 and tier #1, and tier #2 and tier #3; f – significant differences ($p < 0.05$) between tier #2 and tier #3

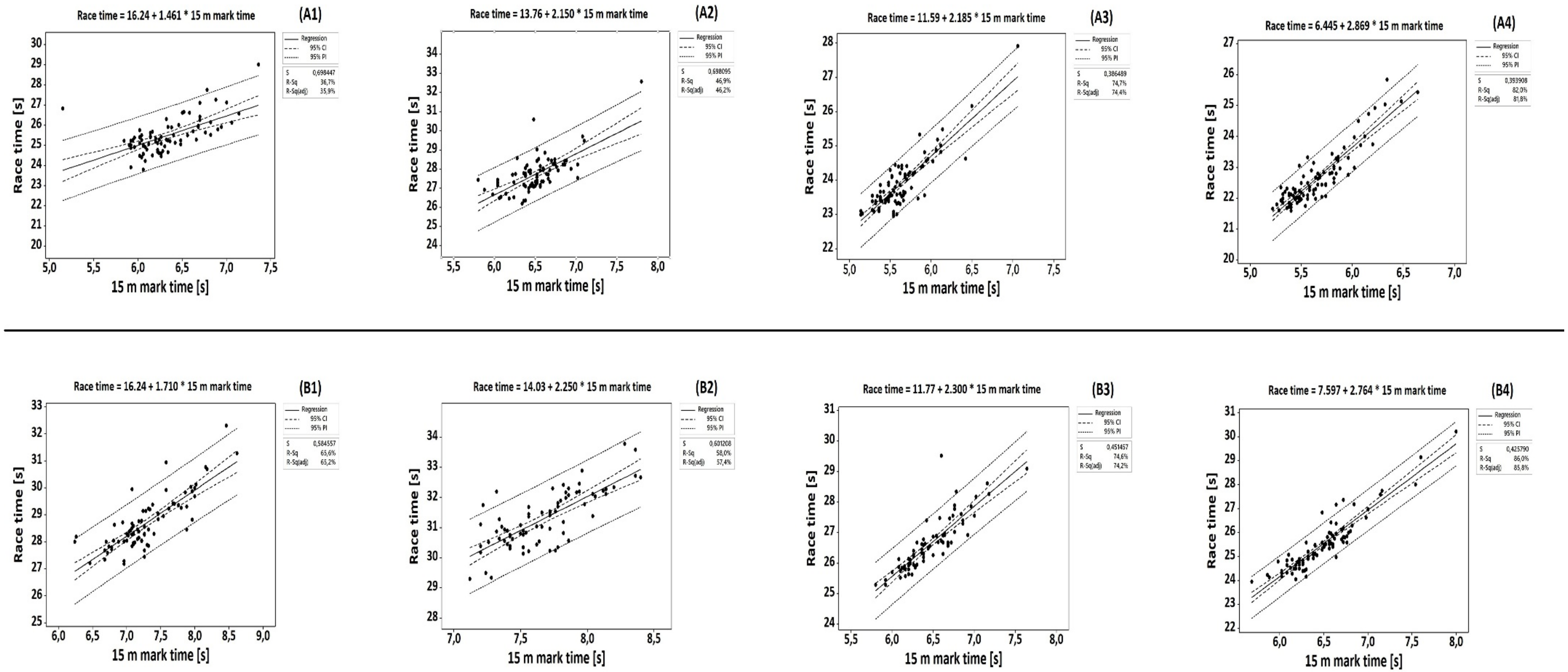

Figure 1. Standardized linear regression between the race time and the 15th meter mark time in all four swim strokes by sex. Panels (A) – male swimmers; Panels (B) – female swimmers. 1 – backstroke; 2 – breaststroke; 3 – butterfly; 4 – freestyle.

4. Discussion

This study aimed to: (i) present normative data of the variables related to the start in the four swim strokes by sex, and; (ii) understand the relationship between the 15th meter mark time and the final race time of the male and female swimmers competing in the four 50 m events at the 2021 European Championships. Besides the final race time, it was shown that for all four swim strokes (both sexes) the 15th meter mark time was the main determinant for the significant tier effect. The start main outcome (i.e., 15th meter mark time) also presented a moderate to very-high relationship with the final race time in males, and a high to very-high in females.

As aforementioned, the start phase of a swim race presents a key-role on short-distance events. Studies aimed to understand which are the best predictors or ways for swimmers to improve their 15th meter mark (Burkhardt et al., 2020; García-Ramos et al., 2015; Thng et al., 2020). The overall information to be retrieved is that a faster start will lead to a better performance (Born et al., 2021; Olstad et al., 2020). Indeed, our data showed that in all four swim strokes, in both sexes, swimmers with better performances (tier #1) were also the ones achieving the 15th meter mark quicker. However, it was possible to note that the different three tiers for all four swim strokes (both sexes) presented a significant tier effect in several starting variables. Overall, in both sexes and for the four swim strokes, swimmers with better performances (tier #1) were the ones presenting fastest times and longer distances, as well as a faster underwater speed. During the start, specifically while in the block phase, swimmers must apply large forces rapidly on the start block. This will maximize the horizontal take-off velocity which will allow them to enter in water farther (Tor et al., 2015; Thng et al., 2020). Based on a systematic review about the relationship between dry-land resistance training and swim start performance it was shown that variables related to lower body strength and power are highly correlated with swim start performance (Thng et al., 2019). Furthermore, post-activation potentiation can also produce meaningful improvements in swim start performance (Cuenca-Fernández et al., 2019; Thng et al., 2019). Despite most considerations are for the freestyle start, one can also indicate that the same rational can be used for the remaining swim strokes. For instance, for the backstroke, studies have shown that kinematics and kinetic variables related to the flight and entry phases of the start ensured a shorter backstroke start time (Takeda et al., 2014). Specifically, a less deceleration can occur due to a smaller entry range and the arched-back posture was necessary in performing the hole entry technique (Takeda et al., 2014). In the case of breaststroke, it was noted that the drag coefficient in the first glide position (arms fully extended over the head) was significantly lower than the one noted in the second glide position (arms fully extend along the trunk) of the underwater breaststroke stroke (Vilas-Boas et al., 2010). Thus, the underwater phase in breaststroke plays a key-role on the start performance. As for butterfly, Gonjo & Olstad (2020) noted that in male butterfly sprinters the underwater phase was largely correlated with the start performance. Notwithstanding, most of these considerations are for male swimmers. Literature lacks information about the behavior of female swimmers in a competition context (Arellano et al., 2022). Our data showed that, regarding this topic, the female swimmers' trend was like their males' counterparts. That is, a significant and moderate to strong tier effect was noted for the final race time and 15 m mark time (i.e., start main outcome). Afterwards, the variables responsible for this start significant effect could be different depending on each tier characteristics.

Despite the swim stroke, if swimmers adopt the best streamlined position after the water entry and during the underwater phase, the force generated on the start block will also help swimmers on promoting a faster underwater speed (Calderbank et al., 2020; Thng et al., 2021). This can also be enhanced with powerful underwater dolphin kicks (except in breaststroke due to ruling constraints) (Ikeda et al., 2021). Therefore, promoting a higher impulse in the block phase does not guarantee a better start performance if swimmers do not try to reduce as much as possible their body surface in contact with water to reduce the drag force (Morais et al., 2020; Stosic et al., 2020). Added to that, it was noted that a greater angular displacement of the lower trunk increased angular displacement of the shoulder, knee, and lower leg during the dolphin kick (Ikeda et al., 2021). Main rational suggests that angular displacement of the lower trunk plays a key-role on the dolphin kick performance (Ikeda et al., 2021). Another phase of the start that plays a determinant role on the start performance is the transition between underwater to surface (Ruiz-Navarro et al., 2021; Trinidad et al., 2020, Veiga et al., 2016). Overall, it was noted that the transition phase is faster in freestyle and butterfly than in backstroke or breaststroke (Trinidad et al., 2020). Despite this, the transition phase plays a determinant factor in all four swim strokes but with different roles (Stosic et al., 2020). Indeed, our data revealed that this phase was determinant on the tier effect based on the underwater break time or distance. However, swimmers with better performances in the race (tier #1) didn't always present the fastest underwater break time or the longest underwater break distance. This indicates that depending on the swimmers' performance level different starting strategies can be used aiming to improve the 15th meter mark. Therefore, coaches must be aware that a "standard" start strategy may not be the proper one to a given swimmer. They are advised to analyze the swimmers' characteristics to design the fittest strategy for a given swimmer.

Regarding the 15th meter mark time and final race time, our data shows that it is possible to predict the final race time of the four swim strokes (both sexes) based on the time spent to achieve the 15th meter mark. As aforementioned several studies aimed to understand how to improve the swimmers' start performance. On the other hand, fewer studies related the start performance and the final race time (Marinho et al., 2021; Arellano et al., 2022). Overall, it was noted that a strong and significant relationship exists between the 15th meter mark and the final race time in sprinting events at least in freestyle (Marinho et al., 2021) and breaststroke (Olstad et al., 2020). In our study, this relationship was only very-high and high (both sexes) in the freestyle and butterfly stroke, respectively. It was also high (but with lower magnitude) for breaststroke and backstroke in females, and moderate for both strokes in males. Thus, one can state that the 15th meter mark time presents a strong relationship with the fastest swim strokes (i.e., freestyle and butterfly). Indeed, in our data, the freestyle start (15th meter mark time) accounted for 24.94 ± 0.56% and 25.39 ± 0.60% for males and females, respectively. This was the highest percentage observed within the four swim strokes in both sexes. Studies about race analysis, at least in males' freestyle sprinting events, noted that the 15th meter mark was significantly correlated to the final race time (Arellano et al., 2018; Marinho et al., 2021). This relationship was also noted in males' breaststrokers but for the 100 m event. As for females, the same trend was verified but only in freestyle (Arellano et al., 1992). Recently, Arellano et al. (2022) reported up-to-date correlation data between the 50 m race times in all four swim strokes by sex. The authors noted that a significant correlation was found between the 50 m final race time and the 15th meter mark time in freestyle, backstroke, and butterfly only in females. Curiously, these findings are not completely related to ours concerning the males' performances. We noted a significant (high to very-high) relationship between the final race time and the 15th meter mark in male and female swimmers. Therefore, more studies should be conducted about this topic.

5. Practical Applications

Data provided by this study provide more and insightful information for coaches and swimmers about the relationship between the start performance and the race time in a competition context (in all four swim strokes and both sexes). It was shown that the start performance (15th meter mark time) has a stronger relationship with the fastest swim strokes (freestyle and butterfly). Each tier presented different approaches to achieve the 15th meter mark. These results will help coaches and swimmers to better understand how to design specific starting strategies in all four swim strokes, and especially in female swimmers (where evidence is lower than in their male counterparts). Future studies about this topic must be conducted in several age-groups or different competitive levels.

6. Conclusions

For male and female swimmers competing in the four 50 m events at the 2021 European Championships it was possible to note that the variables that better discriminated the tiers was the 15th meter mark time. This enhances the fact that better performers at the end of the 50 m sprinting events were also the ones achieving sooner the 15th meter mark. The underwater phase and its transition to surface revealed to be a determinant common factor to the tier effect in all four swim strokes. This indicates that despite each swim stroke starting particularities, this phase is important in all of them. The 15th meter mark presented a high to very-high relationship with the final race time in all four swim strokes in both sexes. This highlights the importance of the start to the final race time in all four swim strokes and in both sexes (being stronger in freestyle).

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