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Profile of female swimmers competing in the 50 m events at the 2021 LEN European Championships

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ABSTRACT

This study aimed to understand whether there are significant differences in stroke kinematics between tiers in female swimmers competing in the four 50 m events of the 2021 European Championships and to understand the speed-time relationship in the four race events per tier. Participants were all female swimmers (backstroke: 78 swimmers; breaststroke: 75 swimmers; butterfly: 74 swimmers; freestyle: 87 swimmers) who participated in the 50 m events at the 2021 LEN European Championships held in Budapest (i.e. heats, semi-finals, and final). For each swimming stroke, swimmers were divided into three tiers (best-performing swimmers, intermedium-performing swimmers, and poorest-performing swimmers). Swimming speed revealed a significant tier effect ($p < 0.05$) in all race sections for all swimming strokes. The other stroke kinematic variables revealed divergent findings, but the stroke frequency presented an overall tier effect ($p < 0.05$) across all four swimming strokes. Curve fitting for all swimming strokes and tiers revealed a cubic relationship. Thus, it should be considered that female swimmers who compete in 50 m events in major competitions adopt an all-out strategy. The present data provide coaches with insightful information about the main trend in 50 m sprint events, specifically in each section of the race.

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KEYWORDS
Swimming; race analysis; swimming strokes; curve fitting

1. Introduction

Race analysis in sports performance plays a fundamental role in the improvement of athletes (Gill et al., 2014; Sánchez et al., 2021). This allows coaches to objectively/impartially and reliably collect information such as kinematics variables on each event or race (Barbosa et al., 2021). Hence, it can be considered the best way to understand the biomechanical profile of each athlete, as it is being analysed in a real context or competition.

In this sense, the start and turn phases are well characterised in swimming events as acyclic periods of great interest in sports analysis (Sánchez et al., 2021). Clean swimming and finishing phases are the other key factors that coaches and

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swimmers have focused on to provide relevant information about the final performance (Gonjo & Olstad, 2020, 2021; Morais, Marinho, et al., 2019; Veiga & Roig, 2017).

Regarding stroke events, long-course freestyle events have been widely analysed by researchers and race analysts, regardless of the distance (Huot□marchand et al., 2005; Lara & Del Coso, 2021; Mohamed et al., 2021), but the literature provides scarce information about backstroke, butterfly, and breaststroke events. Nevertheless, there are studies that focus on characterising the pacing of breaststroke (Nicol et al., 2021; Sánchez et al., 2021), backstroke (Veiga et al., 2013), and butterfly swimmers (Gonjo & Olstad, 2020).

Furthermore, distances of 100 m or more have been reported in the literature as the most common distances to be evaluated. The race pace was based on lap-to-lap performance and stroke kinematics (Lara & Del Coso, 2021; Morais, Barbosa, et al., 2019).

As 50 m events in long course consist of a single lap, new trends in swimming events analysis have reported greater and deeper information about swimmers' profiles by diving the length of the pool into 5 metres sections (Morais, Barbosa, Lopes, et al., 2022; Morais, Barbosa, Silva, et al., 2022; Simbaña-Escobar et al., 2018). They observed that male swimmers achieved a rapid acceleration at the start followed by a gradual decrease in swimming speed over the course of the race as fatigue sets in in the 50 m freestyle events.

Thus, it can be stated that there is a lack of evidence in the women's 50 m events in backstroke, breaststroke, and butterfly. In addition, the profile of female 50 m swimmers is still poorly investigated in any swimming stroke. Thus, the characterisation of the female 50 m events needs to be addressed to provide more detailed and specific kinematic knowledge.

Therefore, the main objectives of this study were to: (i) understand whether there are significant differences in stroke kinematics between tiers (in all race sections) in female swimmers who compete in the four 50 m events of the 2021 European Championships, and; (ii) understand the speed-time relationship in the four race events by tier. It was hypothesised that: (i) female swimmers would present a significant tier effect in all stroke kinematic variables (in all race sections), and; (ii) all tiers would present a cubic speed-time relationship in the four swimming strokes.

2. Methods

2.1. Participants

Participants were female swimmers (backstroke: 78 swimmers; breaststroke: 75 swimmers; butterfly: 74 swimmers; freestyle: 87 swimmers) who competed in the 50 m events at the 2021 LEN European Championships held in Budapest (i.e. heats, semi-finals, and final). Only swimmers with final times were analysed. The 50 m backstroke performance reached 94.12 ± 3.12% of 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).

2.2. Race analysis

The official race times and block times were retrieved from the official competition website (http://budapest2020.microplustiming.com/indexBudapest2021_web.php). All video clips have been provided in high definition ($f = 50$ Hz). The setup system delivered 10 pan-tilt-zoom cameras. Each swimmer was recorded by a camera (i.e. one camera per lane), which enabled the analysis of the start and finish individually. Pool calibration was performed before each session. The start strobe lights were synchronised with the official timing system and were visible to all cameras. The start strobe light was used as a reference to set the timestamp in the race analysis software (Morais, Marinho, et al., 2019). Two expert race analysts evaluated each race analysis in a dedicated software based on the provided video clips. That is, each swimmer was analysed individually based on video analysis.

2.3. Race sections

The start (i.e. the time lag between the starting signal and the 15 m mark) was converted into speed. This is the section S0-15 m (i.e. time between 0 and 15 m). The other sections are: (i) S15–25 m (time between the 15th and 25th metre); (ii) S25–35 m (time between the 25th and 35th metre); (iii) S35–45 m (time between the 35th and 45th metre), and; (iv) S45–50 m (time between the 45th and 50th metre – finish) (Morais, Barbosa, Silva, et al., 2022). Figure 1 represents the race sections of the swimming pool.

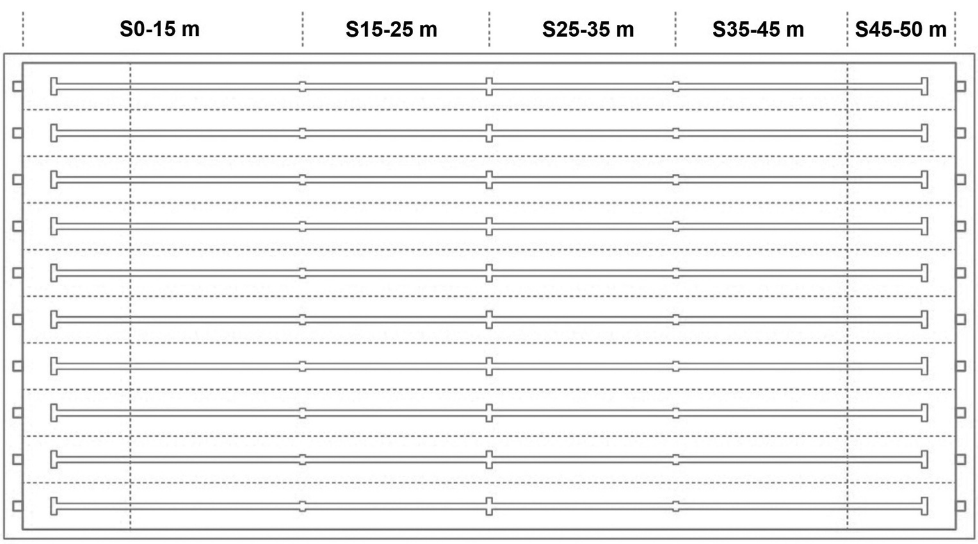

Figure 1. Schematic of the race sections.

2.4. Data collection

All the following kinematic variables were measured after the S0–15 m section: (i) the clean swimming speed (m/s); (ii) the stroke frequency (SF, Hz); (iii) the stroke length (SL, m), and; (iv) the stroke index (SI, m^2/s). The clean swimming speed was calculated as v = d/t, in which d is the distance (m) and t is the time (seconds). The SF was obtained by computing the period of the time spent to complete a full stroke cycle (during four consecutive strokes). The SL was calculated as SL = v/SF (Craig & Pendergast, 1979), and the SI as SI = v · SL (Costill et al., 1985). The finish time and speed started to be measured when the swimmer's head reached the 45^{th} metre mark and stopped when the swimmer's hand touched the end wall. Therefore, a speed correction was made based on the time it would take the swimmer's head to complete the remaining distance (Thompson et al., 2000).

The agreement between the two analysts was assessed using the Intraclass Correlation Coefficient (ICC). Race analysis was performed on a time basis for two situations: (i) to calculate swimming speed based on the time spent between the pool marks, and; (ii) to calculate SF. The ICC between the two analysts for swimming speed and SF was 0.998 and 0.997, respectively (very-high agreement).

2.5. Statistical analysis

The Kolmogorov-Smirnov test and Levene's test were used to assess the normality and homoscedasticity, respectively. The mean plus one standard deviation was computed as descriptive statistics. For each race event, the dataset was divided into three tiers: (i) tier #1 – best-performing swimmers; (ii) tier #2 – intermedium-performing swimmers; (iii) tier #3 – poorest-performing swimmers.

The swimmers' tier effect for all kinematic variables was computed using one-way ANOVA ($p < 0.05$). 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).

For each race event (i.e. backstroke, breaststroke, butterfly, and freestyle), curve fitting was used to model the speed-time data spread by assigning the "best fit" function throughout the race (Morais, Barbosa, Silva, et al., 2022). It was performed based on the five main sections defined beforehand: (i) S0–15 m; (ii) S15–25 m; (iii) S25–35 m; (iv) S35–45 m, and; (v) S45–50 m. Linear, quadratic, and cubic fits were tested. Trendline, 95 CI, 95% of prediction interval (95PI) and standard error of estimation (SEE) were calculated. The SEE was used as a goodness-of-fit indicator to compare the models (i.e. linear, quadratic, and cubic) (Siegel, 2016). The swimmers' speed variance was assessed based on the persistence of the magnitude of change of a given variable throughout the race. For this, repeated measures ANOVA (i.e. variance between sections) followed by the Bonferroni post-hoc were used to verify significant differences between each speed pairwise ($p < 0.05$).

3. Results

Table 1 presents the descriptive data for the stroke kinematic variables in the 50 m backstroke and breaststroke in all race sections by tier. In the backstroke technique, the greatest tier effect for swimming speed was observed in the S15-25 m race section (F =

Table 1. Descriptive data (mean ± one standard deviation – SD) of all variables measured by race section for the backstroke and breaststroke. It is also presented the tier effect for each variable in each section.

	Mean ±1SD (Tier #1)	Mean ±1SD (Tier #2)	Mean ±1SD (Tier #3)	F	p	η^2
50 m backstroke						
			S0–15 m			
Speed [m/s]	2.17 ± 0.09	2.10 ± 0.09	1.94 ± 0.09	42.546	<0.001	0.532
			S15–25 m			
Speed [m/s]	1.71 ± 0.02	1.69 ± 0.03	1.62 ± 0.04	48.968	<0.001	0.566
SF [Hz]	0.91 ± 0.05	0.92 ± 0.05	0.88 ± 0.06	4.609	0.013	0.109
SL [m]	1.89 ± 0.11	1.80 ± 0.10	1.86 ± 0.12	0.955	0.389	0.025
SI [m^2/s]	3.21 ± 0.20	3.10 ± 0.16	3.01 ± 0.22	6.605	0.002	0.150
			S25–35 m			
Speed [m/s]	1.70 ± 0.06	1.69 ± 0.03	1.59 ± 0.04	35.532	<0.001	0.487
SF [Hz]	0.90 ± 0.05	0.91 ± 0.05	0.85 ± 0.05	9.946	<0.001	0.210
SL [m]	1.89 ± 0.12	1.82 ± 0.09	1.89 ± 0.11	2.512	0.088	0.063
SI [m^2/s]	3.21 ± 0.30	3.00 ± 0.17	2.96 ± 0.21	8.437	<0.001	0.184
			S35-45 m			
Speed [m/s]	1.63 ± 0.05	1.61 ± 0.02	1.56 ± 0.05	18.035	<0.001	0.325
SF [Hz]	0.89 ± 0.05	0.89 ± 0.05	0.83 ± 0.06	13.282	<0.001	0.262
SL [m]	1.86 ± 0.13	1.82 ± 0.10	1.91 ± 0.12	3.780	0.027	0.092
SI [m^2/s]	3.03 ± 0.27	2.93 ± 0.18	2.98 ± 0.21	1.535	0.222	0.039
			S45–50 m			
Speed [m/s]	1.53 ± 0.08	1.48 ± 0.07	1.42 ± 0.05	16.825	<0.001	0.310
SF [Hz]	0.87 ± 0.05	0.87 ± 0.06	0.81 ± 0.05	10.068	<0.001	0.212
SL [m]	1.78 ± 0.14	1.71 ± 0.16	1.76 ± 0.14	1.505	0.229	0.039
SI [m^2/s]	2.72 ± 0.31	2.53 ± 0.32	2.51 ± 0.25	3.864	0.025	0.093
50 m breaststroke						
			S0–15 m			
Speed [m/s]	2.01 ± 0.05	1.98 ± 0.05	1.88 ± 0.06	40.478	<0.001	0.529
			S15–25 m			
Speed [m/s]	1.52 ± 0.15	1.51 ± 0.03	1.46 ± 0.03	3.618	0.032	0.664
SF [Hz]	1.04 ± 0.09	1.01 ± 0.09	0.96 ± 0.08	5.214	0.008	0.127
SL [m]	1.47 ± 0.18	1.51 ± 0.13	1.52 ± 0.12	0.922	0.402	0.025
SI [m^2/s]	2.26 ± 0.38	2.28 ± 0.18	2,22 ± 0.17	0.274	0.761	0.008
			S25–35 m			
Speed [m/s]	1.54 ± 0.04	1.49 ± 0.03	1.44 ± 0.03	68.010	<0.001	0.654
SF [Hz]	1.03 ± 0.09	1.00 ± 0.09	0.97 ± 0.09	4.355	0.016	0.110
SL [m]	1.51 ± 0.02	1.51 ± 0.13	1.51±.013	0.045	0.956	0.001
SI [m^2/s]	2.32 ± 0.18	2.25 ± 0.18	2.17 ± 0.18	4.088	0.021	0.102
			S35–45 m			
Speed [m/s]	1.51 ± 0.03	1.46 ± 0.02	1.43 ± 0.02	70.922	<0.001	0.663
SF [Hz]	1.03 ± 0.09	0.99 ± 0.09	0.96 ± 0.08	4.058	0.021	0.101
SL [m]	1.49 ± 0.12	1.50 ± 0.13	1.50 ± 0.12	0.026	0.975	0.001
SI [m^2/s]	2.26 ± 0.19	2.18 ± 0.19	2.14 ± 0.18	2.732	0.072	0.071
			S45–50 m			
Speed [m/s]	1.35 ± 0.04	1.31 ± 0.05	1.28 ± 0.05	14.834	<0.001	0.292
SF [Hz]	1.03 ± 0.08	0.99 ± 0.08	0.94 ± 0.09	6.813	0.002	0.159
SL [m]	1.32 ± 0.12	1.34 ± 0.13	1.38 ± 0.15	1.132	0.328	0.030
SI [m^2/s]	1.78 ± 0.19	1.76 ± 0.20	1.77 ± 0.23	0.126	0.882	0.003

Note: S – race section; SF – stroke frequency; SL – stroke length; SI – stroke index. F – F-ratio; p – significance level; η2 – eta square (effect size index).

48.968, $p < 0.001$, $\eta^2 = 0.566$), for the SF in S35-45 m (F = 13.282, $p < 0.001$, $\eta^2 = 0.262$), and for the SI in S25-35 m (F = 8.437, $p < 0.001$, $\eta^2 = 0.184$). On the other hand, the SL showed a significant tier effect only in the S35-45 m section (F = 3.780, $p = 0.027$, $\eta^2 = 0.092$). In breaststroke, the greatest tier effect for swimming speed was observed in the S35-45 m section (F = 70.922, $p < 0.001$, $\eta^2 = 0.663$), for the SF in S45-50 m (F = 6.813, $p = 0.002$, $\eta^2 = 0.159$), and for the SI significant differences were observed only in the S25-35 m section (F = 4.088, $p < 0.021$, $\eta^2 = 0.102$). On the other hand, the SL did not present a significant tier effect in any section.

Table 2 presents the descriptive data for the stroke kinematic variables in the 50 m butterfly and freestyle in all race sections by tier. In butterfly, the greatest tier effect for swimming speed was observed in the S0-15 m race section (F = 81.881, $p < 0.001$, $\eta^2 = 0.698$), for the SF in S25–35 m (F = 7.277, $p = 0.001$, $\eta^2 = 0.170$), for the SL in S15–25 m (F = 6.902, $p = 0.002$, $\eta^2 = 0.163$), and for the SI in S15–25 m (F = 19.639, $p < 0.001$, $\eta^2 = 0.356$). In freestyle, the greatest tier effect for swimming speed was observed in the S35–45 m race section (F = 82.025, $p < 0.001$, $\eta^2 = 0.664$), for the SF in S35–45 m (F = 4.144, $p = 0.019$, $\eta^2 = 0.091$), for the SL in S15–25 m (F = 6.156, $p = 0.003$, $\eta^2 = 0.129$), and for the SI in S15–25 m (F = 27.444, $p < 0.001$, $\eta^2 = 0.398$).

Figure 2 shows the speed-time curve of the female swimmers in backstroke (Panels A), breaststroke (Panels B), butterfly (Panels C), and freestyle (Panels D). Suffixes 1, 2 and 3 correspond to tier #1 swimmers (best-performers), tier #2 swimmers (intermedium-performers), and tier #3 swimmers (poorest-performers), respectively. For all swimming strokes, a cubic relationship was found in the speed-time curve in all three tiers. For backstroke (tier #1: SEE = 0.065; tier #2: SEE = 0.056; tier #3: SEE = 0.062), significant differences ($p < 0.05$) were found between consecutive sections in all three tiers, except between the sections S15–25 m and S25–35 m in tier #1. For breaststroke (tier #1: SEE = 0.038; tier #2: SEE = 0.038; tier #3: SEE = 0.039), significant differences ($p < 0.05$) were found between consecutive sections in all three tiers, except between the S15–25 m and the S25–35 m sections in tier #1 and tier #2 and between the S25–35 m and the S35–45 m sections in tier #3. For butterfly (tier #1: SEE = 0.042; tier #2: SEE = 0.042; tier #3: SEE = 0.073), significant differences ($p < 0.05$) were found between consecutive sections in all three tiers, except between the S15–25 m and the S25–35 m sections and between the S25–35 m and the S35–45 m sections in tier #3. For freestyle (tier #1: SEE = 0.050; tier #2: SEE = 0.052; tier #3: SEE = 0.081), significant differences ($p < 0.05$) were found between consecutive sections in all three tiers.

4. Discussion

The main purposes of this study were to understand whether there are significant differences in stroke kinematics between tiers (in all race sections) in female swimmers competing in the four 50 m events of the 2021 European Championships and to understand the speed-time relationship in the four race events by tier. The results showed that in the four swimming strokes a significant tier effect was observed in swimming speed in all sections of the race. The other measured variables (SF, SL, and SI) showed divergent results, i.e. a significant tier effect was observed in some race sections. The speed-time

Table 2. Descriptive data (mean ± one standard deviation – SD) of all variables measured by race section for the butterfly and freestyle strokes. It is also presented the tier effect for each variable in each section.

	Mean ±1SD (Tier #1)	Mean ±1SD (Tier #2)	Mean ±1SD (Tier #3)	F	p	η^2
50 m butterfly						
			S0–15 m			
Speed [m/s]	2.44 ± 0.05	2.32 ± 0.06	2.21 ± 0.08	81.881	<0.001	0.698
			S15–25 m			
Speed [m/s]	1.83 ± 0.03	1.80 ± 0.03	1.72 ± 0.05	43.778	<0.001	0.552
SF [Hz]	1.07 ± 0.04	1.10 ± 0.06	1.05 ± 0.07	5.473	0.006	0.134
SL [m]	1.71 ± 0.07	1.63 ± 0.08	1.65 ± 0.10	6.902	0.002	0.163
SI [m^2/s]	3.14 ± 0.15	2.93 ± 0.16	2.83 ± 0.20	19.639	<0.001	0.356
			S25–35 m			
Speed [m/s]	1.80 ± 0.02	1.77 ± 0.02	1.70 ± 0.06	50.131	<0.001	0.585
SF [Hz]	1.03 ± 0.04	1.05 ± 0.05	1.02 ± 0.06	7.277	0.001	0.170
SL [m]	1.72 ± 0.06	1.65 ± 0.08	1.67 ± 0.09	6.345	0.003	0.152
SI [m^2/s]	3.11 ± 0.12	2.92 ± 0.15	2.84 ± 0.21	19.107	<0.001	0.350
			S35–45 m			
Speed [m/s]	1.77 ± 0.03	1.74 ± 0.03	1.68 ± 0.07	22.812	<0.001	0.391
SF [Hz]	1.03 ± 0.04	1.05 ± 0.05	1.00 ± 0.06	6.132	0.006	0.147
SL [m]	1.72 ± 0.07	1.67 ± 0.10	1.68 ± 0.10	3.305	0.042	0.085
SI [m^2/s]	3.04 ± 1.42	2.90 ± 0.17	2.82 ± 0.24	9.585	<0.001	0.213
			S45–50 m			
Speed [m/s]	1.44 ± 0.09	1.47 ± 0.05	1.44 ± 0.09	11.277	<0.001	0.241
SF [Hz]	0.98 ± 0.06	1.03 ± 0.05	0.98 ± 0.06	6.382	0.003	0.152
SL [m]	1.47 ± 0.15	1.43 ± 0.09	1.47 ± 0.15	3.006	0.056	0.078
SI [m^2/s]	2.12 ± 0.36	2.11 ± 0.19	2.12 ± 0.36	4.402	0.016	0.110
50 m freestyle						
			S0–15 m			
Speed [m/s]	2.44 ± 0.06	2.32 ± 0.05	2.19 ± 0.11	80.759	<0.001	0.661
			S15–25 m			
Speed [m/s]	1.94 ± 0.04	1.90 ± 0.03	1.80 ± 0.07	69.623	<0.001	0.627
SF [Hz]	1.03 ± 0.05	0.99 ± 0.07	0.99 ± 0.06	3.447	0.036	0.077
SL [m]	1.90 ± 0.09	1.92 ± 0.13	1.83 ± 0.10	6.156	0.003	0.129
SI [m^2/s]	3.69 ± 0.19	3.64 ± 0.24	3.29 ± 0.23	27.444	<0.001	0.398
			S25–35 m			
Speed [m/s]	1.92 ± 0.03	1.86 ± 0.03	1.77 ± 0.07	71.186	<0.001	0.632
SF [Hz]	1.00 ± 0.04	0.96 ± 0.07	0.96 ± 0.07	3.484	0.035	0.077
SL [m]	1.93 ± 0.08	1.94 ± 0.14	1.85 ± 0.12	5.082	0.008	0.109
SI [m^2/s]	3.71 ± 0.18	3.60 ± 0.26	3.28 ± 0.28	24.299	<0.001	0.369
			S35–45 m			
Speed [m/s]	1.88 ± 0.03	1.82 ± 0.03	1.73 ± 0.06	82.025	<0.001	0.664
SF [Hz]	0.97 ± 0.04	0.94 ± 0.07	0.93 ± 0.06	4.144	0.019	0.091
SL [m]	1.93 ± 0.08	1.95 ± 0.14	1.86 ± 0.12	4.412	0.015	0.096
SI [m^2/s]	3.62 ± 0.19	3.55 ± 0.26	3.22 ± 0.25	23.156	<0.001	0.358
			S45–50 m			
Speed [m/s]	1.69 ± 0.07	1.70 ± 0.17	1.60 ± 0.09	6.773	0.002	0.140
SF [Hz]	0.95 ± 0.05	0.92 ± 0.07	0.92 ± 0.07	1.968	0.146	0.045
SL [m]	1.79 ± 0.11	1.86 ± 0.24	1.75 ± 0.13	3.054	0.052	0.069
SI [m^2/s]	3.02 ± 0.29	3.19 ± 0.77	2.79 ± 0.30	4.467	0.014	0.097

Note: S – race section; SF – stroke frequency; SL – stroke length; SI – stroke index. F – F-ratio; p – significance level; η2 – eta square (effect size index).

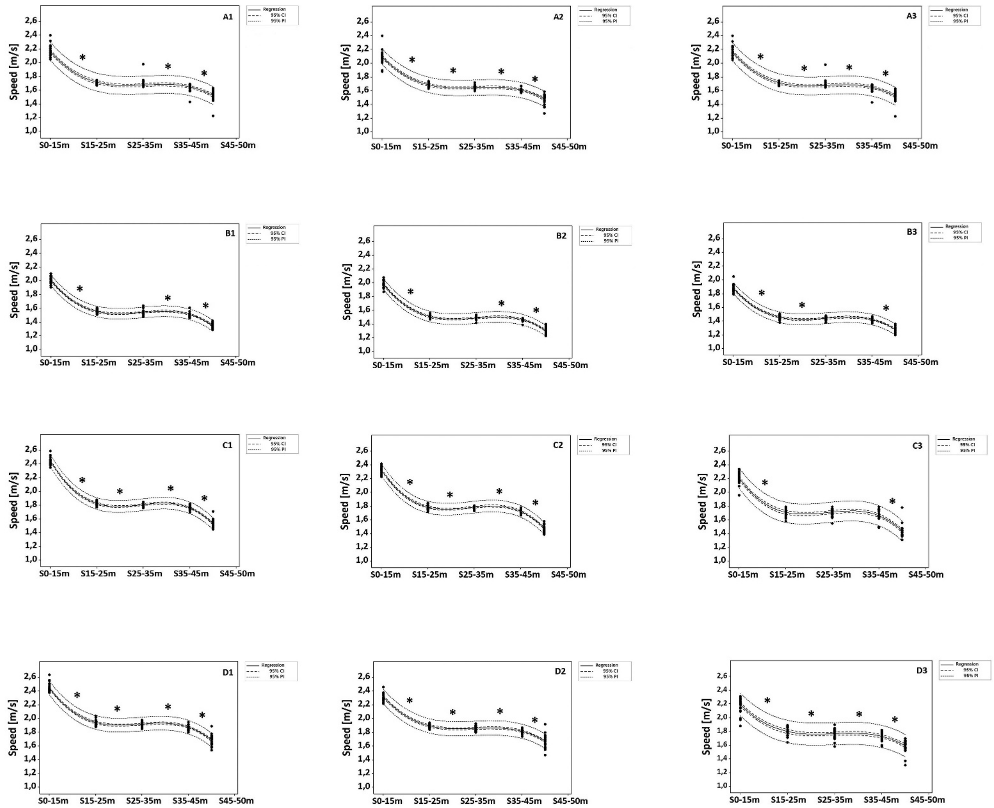

Figure 2. Speed-time curve of the female swimmers. Panels a – backstroke; Panels B – breaststroke. Panels C – butterfly; Panels D – freestyle. 1 – tier #1 swimmers (best-performers); 2 – tier #2 swimmers (intermedium-performers); 3 – tier #3 swimmers – (poorest-performers). CI – 95% confidence intervals; PI – 95% prediction intervals. * - indicate significant differences between pairwise ($p < 0.05$).

curve in the four swimming strokes revealed a cubic relationship with two visible deflection points between sections S0–15 m and S15–25 m and S35–45 m and S45–50 m.

All tiers in the four swimming strokes achieved the fastest swimming speed in the start section (S0–15 m). This is because swimmers took advantage of the block phase by pushing it off. Regarding swimming speed, it was observed that the greatest and most significant tier effect was different among the four swimming strokes: (i) in the backstroke, it happened in the S15–25 m section; (ii) in the breaststroke in S35–45 m; (iii) in the butterfly in S0–15 m, and; (iv) in the freestyle in S35–45 m. These results highlight that, although all 50 m events can be performed as an all-out “strategy”, the greatest differences between tiers in female swimmers are verified in different race sections. Thus, these results show how the variability of female performance is carried out across swimming strokes and race sections.

For the freestyle event, R. D. Arellano et al. (2018) observed that national level female swimmers were significantly faster in every section of the race than regional level swimmers (in short-course swimming pool events). Regarding backstroke, it was observed that backstroke performance was associated with variability in swimming speed, where elite-level swimmers were more unstable and complex than their lower-level counterparts (Fernandes et al., 2022). However, this assumption was based on a maximum 25 m trial and not in all race sections. As far as it is known, there is no evidence on this topic (comparison of tier or group throughout the race) in breaststroke and butterfly sprint events for females. Thus, this study is the first to present normative data on different tiers competing in the 50 m events in the four swimming strokes in the context of real competition for female swimmers. However, it should be noted that other research groups also presented data based on real contexts of women's competition, but with different approaches (R. Arellano et al., 2022; Sánchez et al., 2021). The study by Sánchez et al. (2021) focused on the influence of the underwater phase of national-level breaststrokers in the 50 m event (also in the 100 m), but in a short-course swimming pool. The authors observed that a high velocity during the underwater phase and a short time at 15 m were associated with better performances (Sánchez et al., 2021). On the other hand, R. Arellano et al. (2022) aimed to analyse which race segments and stroke variables in the 50 m events were most modified to achieve improvement over the rounds (i.e. from heats to semis to finals). It was observed that swimmers significantly improved their 50 m performances as the competition progressed. For all strokes, swimmers showed a tendency to reduce the underwater phase and increase the SF in order to increase swimming speed and, consequently, their performance (R. Arellano et al., 2022).

These data revealed that the start section also showed a significant tier effect on the four swimming strokes. In freestyle sprint events, studies have observed significant differences between the best and worst-performing swimmers in this specific race section (S0–15 m, start) (García-Ramos et al., 2015; Morais, Barbosa, Silva, et al., 2022). The main reason for this was the greater force performed in the block phase by the faster swimmers (García-Ramos et al., 2015). Data from the present study show that, in addition to the 50 m freestyle event, the start section also plays a key role in the other 50 m events, where a significant tier effect was observed as well. There is less evidence on this topic in the other swimming strokes and in female swimmers in the context of race analysis. However, Sánchez et al. (2021), analysing breaststroke in short-course, reported that swimmers prone to a faster underwater phase were more likely to perform better at the 15th-metre mark. Moreover, it was also shown for all swimming strokes that swimmers make small improvements in the block phase in the transition from heats, to semis, to finals to obtain better performances (R. Arellano et al., 2022).

A study by Born et al. (2021) provided benchmarks for the start section of the 50 m events performance, but for men and in short-course events. The authors observed that, in all swimming strokes, swimmers in the top-tier percentile (10th) were meaningfully faster to reach the 15th-metre mark than swimmers included in the lower tier (90th) (Born et al., 2021). Also, for men, but in long-course, a similar trend was reported in all four swimming strokes, i.e. the fastest swimmers at the end of the race were also those who reached the 15th-metre mark significantly earlier (Morais, Barbosa, Lopes, et al., 2022). Data found in the literature regarding female swimmers also reported similar findings in all swimming strokes (R. Arellano et al., 2022). Moreover, there are also data referring to short-course freestyle (R. D. Arellano et al., 2018) and breaststroke events (Sánchez et al., 2021). It was observed that national level freestyle swimmers reached the 15th-metre mark faster than their regional-level counterparts (R. D. Arellano et al., 2018), and that breaststroke swimmers with better race performances also achieved the 15th-metre mark sooner (Sánchez et al., 2021).

Regarding the other analysed kinematic variables, they showed different trends in each swimming stroke. In the freestyle event, the SF, SL, and SI presented a significant tier effect throughout the race (except the SF and SL in the last section – S45–50 m). Similar results were observed in short-course events (R. D. Arellano et al., 2018). Nonetheless, this is the opposite trend seen in junior-level male counterparts competing in the same event, in which the differences are only observed in the SL (Morais, Barbosa, Silva, et al., 2022). Thus, it seems that the fastest females produce higher SFs and greater applied force during clean swimming. This allows them to achieve a longer SL and a greater SI. As a significant tier effect was observed in both the SL and SI, this highlights the fact that top-tier swimmers can cover longer distances with fewer strokes (Costill et al., 1985). In backstroke, the SF presented a significant tier effect in all race sections. Conversely, the SL did not. This indicates that for the backstroke sprint, the SF seems to be the main determining factor to improve the final performance. Indeed, R. Arellano et al. (2022) indicated that swimmers tended to increase their SF whenever they wanted to achieve better performances. However, for the 100 m event, it was observed that female backstroke swimmers did not significantly change their SF and SL between laps despite a slight decrease in both (Veiga & Roig, 2017). This highlights the specificity of each event despite both being sprints.

Breaststroke presented similar results to backstroke, in which the SF had a significant tier effect in all race sections (SL did not as it happened in backstroke). The literature does not provide clear evidence about which factors differentiate the best performance from the poorest in breaststroke during sprint races, i.e. 50 m events. Nonetheless, it was shown that between the 100 m (sprint) and 200 m race (middle-distance), breaststroke female swimmers during the 100 m event presented a lower percentage of stroke cycle time (i.e. higher SF) during the pull delay, recovery kick, passive kick, and glide when compared to the 200 m event (Nicol et al., 2021). Thus, it can be suggested that swimmers who compete in the 50 m breaststroke may even decrease the time by performing a higher SF to increase their swimming speed. In fact, also during the clean swimming phase, but for the 100 m, Veiga and Roig (2017) observed that during the first 50 m, the swimming speed was significantly and positively correlated with the SF (i.e. higher cadence led to faster swimming speeds).

Regarding butterfly, swimmers presented results similar to freestylers: a significant tier effect was found throughout the race (except the SL in the last section – S45–50 m). Even though these strokes have different motor control patterns, alternate – freestyle; and simultaneous – butterfly, it seems that the fastest swimmers exhibit a similar pattern during the entire race. Nonetheless, conversely to what happened in freestyle, swimmers in tier #1 presented a slower SF than swimmers in tier #2. Thus, it can be said that the main differentiating factor in the butterfly speed was the ability to generate in-water force to increase the SL. As aforementioned, it has been suggested that top-tier swimmers can cover greater distances with fewer strokes (Costill et al., 1985). Notwithstanding, for the 50 m butterfly event, it should be mentioned that female swimmers tended to significantly increase their SF between the heats to finals in the mid-sections of the swimming pool (R. Arellano et al., 2022). Thus, it can be argued that there are different race strategies from heats to finals, i.e. swimmers tend to increase their SF to achieve better performances. On the other hand, the fastest performances observed in the current study seem to depend more on the increase in SL rather than on SF.

Regarding the speed-time curve, if an all-out race strategy is considered, then sprint events should generate linear relationships. However, for all swimming strokes the best fit was non-linear. Specifically, the speed-time curve in all swimming strokes and tiers exhibited a cubic trend. This type of approach was done for male swimmers who competed in the 50 m freestyle event (Morais, Barbosa, Silva, et al., 2022; Simbaña-Escobar et al., 2018), the 50 m backstroke (Morais, Barbosa, Lopes, et al., 2022), breaststroke (Sánchez et al., 2021), and butterfly events (Morais, Barbosa, Lopes, et al., 2022). These studies also observed a cubic speed-time curve. However, there was no evidence available until now about women's sprint events in competition settings. As it is a cubic relationship, two deflection points were observed (between S0–15 m and S15–25 m; between S35–45 and S45–50 m). This was observed in all strokes and tiers. The first deflection point with the greatest decrease in swimming speed was observed between the average speed reached during the start section (S0–15 m) and the following clean swimming section (S15–25 m). Therefore, the start section can be considered decisive in sprint events in the four swimming strokes (Born et al., 2021; Marinho et al., 2021). The second deflection point was found between the S35–45 m and the S45–50 m sections. At least, studies in freestyle sprint events reported that swimmers tend to slow down significantly in the final section (Morais, Barbosa, Silva, et al., 2022; R. D. Arellano et al., 2018). This phenomenon may be related to fatigue. However, there is still lack of evidence on this topic in other swimming strokes, especially in female swimmers. Notwithstanding, it was recently reported that male sprinters who compete in the 50 m backstroke, breaststroke, and butterfly also experienced a slowdown in the final section (Morais, Barbosa, Lopes, et al., 2022). In the present study, female swimmers included in all tiers and in all swimming strokes also showed an acute drop in swimming speed between the S35–45 m and the S45–50 m sections. In fact, in both pairwise (S0–15 m vs. S15–25 m, and S35–45 vs. S45–50 m), significant differences in swimming speed were observed. Thus, it can be stated that swimmers who are able to reach faster swimming speeds at the beginning and do not slow down so much at the end of the race present better performance times.

5. Conclusions

This study presents normative data for the stroke kinematics of female sprinters who competed in the four 50 m events. In the four swimming strokes, a significant tier effect was observed for the swimming speed in all race sections. Swimmers included in tier #1 (fastest tier) in the four swimming strokes presented the fastest swimming speed in all race sections. The other variables related to stroke kinematics (SF, SL, and SI) presented divergent results. The speed-time curve in the four swimming strokes revealed a cubic relationship with two visible deflection points (beginning and end of the race). Coaches and swimmers should be aware that reaching faster swimming speeds at the start and being able to not drop swimming speed at the end of the race is a key factor in achieving better performances.

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