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Swim start and performance in 50 m freestyle in different age categories of competitive swimmers

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Abstract

Background and Study Aim In international races, the winners are decided by hundredths of a second, which is why the swim start plays an important role, especially in the sprint disciplines. The aim of the study is to reveal the differences in kinematic parameters of start and performance in the sprint 50 m freestyle discipline based on gender in different age categories of competitive swimmers at international competitions organized in Slovakia.

Material and Methods The sample consisted of 180 females and 189 males who were divided into age categories (K1, K2, K3). SwimPro cameras and Dartgish software were used to monitor kinematic parameters. The parameters monitored were - block time (BT), time (FT) and distance (FD) of flight, time (UWT) and distance (UWD) underwater, time to 15 m (T15), 25 m (T25) and 50 m (T50). Data were tested by Shapiro-Wilk, Kurskal-Wallis ANOVA and Mann-Whitney U test in Statistica 13.5.

Results In the phase above water level, there were greater differences ($p<0.01$) in females than in males. Inter-sex differences ($p<0.01$) were evident in FT in K3, K2 and in FD across all categories. In the underwater phase, differences ($p<0.01$) were evident in both sexes. Inter-sex differences were more evident in UWT ($p<0.01$) than UWD ($p<0.05$). There were inter-sex differences ($p<0.01$) in ST and SD between all categories except K3. At T15, T25 and T50, differences ($p<0.01$) were most pronounced between K3 and K2, K1 in females and between all categories in males. Inter-sex differences ($p<0.01$) were also evident across all categories.

Conclusions The study highlighted differences in 50m freestyle start and performance between age groups and gender, so coaches are advised to design training sessions for swimmers separately.

Keywords: kick start, kinematic analysis, sprint swimming, biomechanics

Introduction

All winners in sprint events need to have the best possible starts, free swimming, turn and finish. Therefore, swimmers need to be continuously analysed, for example using video, to receive relevant information about their performances [1, 2, 3] More studies have focused on track swimming as an acyclical movement such as a start or a turn [2, 4, 5], but there are also studies that have addressed these phases [6, 7, 8].

The 50 m sprinting event should be considered as a whole, a performance that involves many variables that contribute to the success of the sprinter [9]. It is therefore a multifactorial performance. From this point of view, the start is one of the essential phases of any sprinter's discipline, as the other phases will depend on this phase. The start can be characterized as the time from the sounding of the sound signal until the swimmer crosses the 15 m distance with the head [10, 11]. One of the key parameters of the 15 m start is the horizontal take-off velocity (81%). The parameter should be paid attention to by coaches and swimmers [10], yet all parameters that contribute to the performance in the start should be monitored. Some studies have also looked at various changes on the starting block such as changing the back support or the position of the centre of gravity on the starting block. Others have focused on the preferred or dominant lower limb on the front edge of the starting block or the width of the stance. Each of these studies showed some results that were particularly valid for elite swimmers, as they were the study population in most of the studies. The flight phase accounted for 65% of the 5 m start distance performance, with the key parameters being the angle of the kick-off and the time to 2 m distance [11]. At 15 m distance, this phase contributed 5% [10]. During this phase it is important to note that the swimmer's body already has some momentum. Swimmer starts to flex in the pelvis and enter the water. It means that the body is transitioning from air to liquid where it starts to have water resistance. Therefore, the angle of entry is very important [12, 13]. In a study by [14], the entry angle has been shown to affect the phase of gliding,

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its depth, and the average velocity of the phase underwater. When entering the water, swimmers perform a butterfly kick just before their feet are submerged in the water [15]. Other studies [16, 17, 18] point out the optimal phase of gliding, which can be divided into the gliding phase and the first strokes until the swimmer begins to swim above the water surface [19.20]. In a study by [21], they compared three levels of underwater trajectory below the water surface. Results revealed that swimmers should swim longer and perform their first kick slightly later, at 6.6 m when reaching a depth of -0.92 m. It resulted in minimizing the loss of velocity during the underwater phase. [19] reviewed studies dealing with the underwater undulatory swimming cycle. Information about the determinants of underwater undulatory swimming cycle performance was inconsistent due to inconsistencies in the definition of kinematic parameters. The swim phase up to 15 m distance (start) accounts for 28% of the total time for this distance [10]. Previous knowledge suggests that with a shorter swim phase, swimmers perform better in the start [22]. From the perspective of competitive swimming at top events where swimmers compete against each other in individual sprint events, we can see minimal difference in performance between competitors [2, 23, 24, 25]. Nevertheless, the short duration induces, and the maximum intensity induces a decrease in velocity over the entire track [26]. For example, some results from the 2021 European Championships show increasing performance in the 100 and 200 m events from heats to finals [27]. Authors suggest that swimmers were saving their energy for the finals, where the medal is already decided, as opposed to heats [25]. Inter-sex differences were found at the 2016 European Championships. In the freestyle, men were faster ($p<0.05$) compared to women in the start (start reaction time, flight time, under water time, time to 15 m). A similar pattern was observed at the 2021 European Championships in Budapest [25].

Most studies have focused on elite swimmers. From our point of view, studies should also look at the performance of swimmers in different age categories. Therefore, the aim of the study is to reveal the differences in kinematic parameters of start and performance in the sprint 50 m freestyle discipline. Differences are based on gender in various age categories of competitive swimmers at international competitions organized in Slovakia. It was hypothesized, that start and swim performance would improve over the age categories, and that these changes would be a consequence of the improvement in the start and swim performance variables.

Materials and Methods

Participants

The sample of 180 female swimmers was divided according to age categories as follows - K1 - year of birth 2007 and older, K2 - year of birth 2008 and 2009 and K3 - year of birth 2010 and 2011. The swimmers were mainly from the Slovak Republic, Czech Republic, Estonia, and Ukraine. The pool of 189 swimmers was divided into categories K1 - year of birth 2006 and older, K2 - year of birth 2007 and 2008 and K3 - year of birth 2009 and 2010. The swimmers were mainly from the Slovak Republic, Czech Republic, Estonia, Luxembourg, and Ukraine (Table 1).

Research Design

The monitored event was the 50 m freestyle event at the Orca Cup in Bratislava 05.-07.05.2023. The pool was an 8 lane, 50 m with a lane width of 2.5 m. There was also a warm-down swimming pool available, which was in the next building. The timing was electronic - SwissTiming Quantum Aquatics.

At the start of the day everyone had a warm-up swimming according to the categories K3 - 7.50 - 8.10am, K2 - 8.10 - 8.30am and K1 - 8.30 - 9.00am. Warm-up swimming was for both sexes. The 50m freestyle was the first event on the schedule (06.05.2023) and was divided into 25 women's and 24 men's heats according to performance, which were swum consecutively. Thus, a total of 369 starts were made. One female and one male from the K3 category were disqualified. Starts were taken from OSB 11 start blocks, which were linked to the SwissTiming Quantum Aquatics system. A SwimPro camera system was used to measure kinematic parameters. The camera system was located above the water surface. The first camera was at 1.6 m, the second at 10 m, the third at 15 m and the fourth at 25 m from the pool wall where the start blocks are located. All cameras were at a height of 4.5 m. The pool was illuminated by halogen bulbs. The camera system operated at 50Hz with a shutter speed of 1/1000 s. The phases monitored were the above-water, underwater and swim phases on the track. The kinematic parameters monitored were above-water phase - block time, flight time, flight distance;

Table 1. Characteristics of the research sample

Participant characteristics	Female			Male		
Categories	K1	K2	K3	K1	K2	K3
n	57	64	59	56	68	65
Entry time (s)	33.78±4.12	30.69±2.10	30.32±4.50	31.29±2.94	27.93±2.20	25.19±1.45

underwater phase - underwater time, underwater distance (gliding and first swimming strokes); swim phase - time to 15 m; time to 25 m; time to 50 m (Table 2).

Parameters such as start reaction at the starting block and time to 50m were provided by the event organisers and resulted from the SwissTiming Quantum Aquatics electoral system for swimming. All resulting 50 m distance times are available on the internet either on the swimrankings [28]. To assess kinematic parameters, we used Dartfish software (Dartfish ProSuite 4.0, Switzerland), which meets all validity and reliability criteria for measuring kinematic parameters recorded in 2D space [29, 30].

Statistical analysis

We used the Shapiro-Wilk test to assess the normality of the observed selected kinematic variables in each category. We assessed the significance of differences in the observed launch and 50 m power parameters between the K1, K2 and K3 categories using the Kruskal-Wallis ANOVA test. Differences between sexes in the individual K1, K2 and K3 categories were assessed by the Mann-Whitney U test. Tests were assessed at 1% ($p<0.01$) and 5% ($p<0.05$) levels of statistical significance. Statistics were processed using Statistica 13.5 software.

Results

The men percentage contribution of start phases

The above-water phase accounted for 12-14% of the total start (15 m distance), depending on gender and category. For females, BT and FT accounted for 9% and 3% on average, respectively. For men, BT accounted for an average of 10% and FT 4%. The phase underwater accounted for 41% and 42% of the start for women and men, respectively. The swim phase accounted for 47% of the start in women and 44% in men (Table 3).

Above-water phase – block and flight phase

In the female category, the shortest BT was in the K1 category. FT was the shortest in the K3 category, while the largest FD was registered in K1. Significance of differences ($p<0.01$) between female categories was evident in BT between K3-K1 and FD between K3 and K2-K1 categories. For males, the results above-water level was the same. The shortest BT was in the K1 category. FT was the shortest in the K3 category, while the largest FD

Table 2. Detailed description of the above-water, underwater and swim phases parameters

Phase	Variables		Definition
Above-water	Block time (BT)	(s)	The time from the sounding of the starting signal to the swimmer's feet leaving the starting block at the rebound.
	Flight time (FT)	(s)	The time from the time the swimmer's feet leave the starting block at the rebound to the first contact of the swimmer's hands with the water surface.
	Flight distance (FD)	(m)	The distance from the time the swimmer's feet leaves the starting block at the rebound to the first contact of the swimmer's hands with the water surface.
Underwater	Underwater time (UWT)	(s)	The time of the first contact of the swimmer's hands with the surface of the water until the swimmer's head breaks the surface of the water.
	Underwater distance (UWD)	(m)	The distance of the first contact of the swimmer's hands with the surface of the water until the swimmer's head breaks the surface of the water.
Swim	Swim time to 15 m (ST)	(s)	The time of the swim from the time the swimmer's head crosses the surface of the water until the swimmer's head has again crossed the 15 m distance
	Swim distance to 15 m (SD)	(m)	The distance of the swim from the time the swimmer's head crosses the surface of the water until the swimmer's head has again crossed the 15 m distance
	Time to 15 m (T15)	(s)	The time from the sounding of the start signal until the swimmer's head has crossed the water surface at the 15 m distance.
	Time to 25 m (T25)	(s)	The time from the sounding of the start signal until the swimmer's head has crossed the water surface at the 25 m distance.
	Time to 50 m (T50)	(m)	The time from the sounding of the start signal until the swimmer's head has crossed the water surface at the 50 m distance.

was registered in K1. Significance of differences (p<0.01) between categories was only evident in FD and this was between all categories. There were no inter-sex differences in the K3-K1 categories in BT. In FT, inter-sex differences (p<0.01) were evident in K3 and K2. In FD, there were inter-sex differences (p<0.01) between all categories (Table 4).

Underwater phase

The longest UWT and UWD in females were observed in the K1 category. Significance of differences (p<0.05) in UWT was observed between the K3-K1 and K2-K1 categories. Significance of differences (p<0.01) in UWD was observed between the K3 and K2-K1 categories. In males, K2 achieved

Table 3. Percentage of phases at the start of both gender in K3-K1

Phases	Variables	Categories	Female		Male	
			%	∑%	%	∑%
Above-water	BT (s)	K3	9		9	
		K2	9	9	10	10
		K1	9		11	
	FT (s)	K3	3		3	
		K2	3	3	4	4
		K1	3		5	
Underwater	UWT (s)	K3	37		34	
		K2	40	41	44	42
		K1	46		47	
Swim	ST (s)	K3	52		53	
		K2	48	47	42	44
		K1	41		37	

Note: BT – block time; FT – flight time; UWT – underwater time; ST – swim time to 15 m; s - second

Table 4. Kinematic parameters of start and performance in females and males 50 m breaststroke

Variables	Sex	Categories	M	StD	Shapiro-Wilk test		Kruskal-Wallis test		Mann-Whitney U test	
					W	p	H	p	U	p
BT (s)	F	K3	0.75	0.11	0.97	0.21	8.3	K3-K1**	K3FM 1470.00	n.s.
		K2	0.71	0.10	0.98	0.22				
		K1	0.69	0.08	0.98	0.45			K2FM 2019.00	n.s.
	M	K3	0.71	0.13	0.97	0.07	4.68	n.s.		
		K2	0.71	0.09	0.98	0.22			K1FM 1572.00	n.s.
		K1	0.68	0.06	0.96	0.05				
FT (s)	F	K3	0.23	0.08	0.99	0.79	2.17	n.s.	K3FM 1046.00	**
		K2	0.25	0.07	0.99	0.73				
		K1	0.24	0.07	0.98	0.52			K2FM 1588.00	**
	M	K3	0.27	0.08	0.99	0.72	0.34	n.s.		
		K2	0.29	0.08	0.96	0.04			K1FM 1834.00	n.s.
		K1	0.31	0.07	0.98	0.36				
FD (m)	F	K3	2.72	0.17	0.80	0.00	22.02	K3-K2** K3-K1**	K3FM 181.00	**
		K2	2.80	0.11	0.98	0.17				
		K1	3.21	2.02	0.21	0.00			K2FM 468.50	**
	M	K3	2.93	0.11	0.96	0.04	57.29	K3-K2** K3-K1** K2-K1**		
		K2	3.04	0.19	0.89	0.01			K1FM 487.00	**
		K1	3.25	0.28	0.90	0.00				

Count. Table 4.

Variables	Sex	Categories	M	StD	Shapiro-Wilk test		Kruskal-Wallis test		Mann-Whitney U test	
					W	p	H	p	U	p
UWT (s)	F	K3	3.16	0.91	0.97	0.09		K3-K1*	K3FM 987.00	**
		K2	3.14	0.76	0.93	0.00	7.79	K2-K1*		
		K1	3.56	1.19	0.74	0.00			K2FM 2138.00	**
	M	K3	2.72	0.75	0.94	0.00		K3-K2**		
		K2	3.14	0.71	0.96	0.03	14.25		K1FM 1364.00	**
		K1	2.96	0.50	0.99	0.85		K3-K1*		
UWD (m)	F	K3	5.47	1.59	0.98	0.27			K3FM 1181.00	*
		K2	6.28	1.47	0.97	0.37	19.76	K3-K2** K3-K1**		
		K1	6.51	2.75	0.72	0.00			K2FM 1702.00	*
	M	K3	5.12	1.51	0.96	0.03		K3-K2**		
		K2	6.81	1.49	0.97	0.09	64.76	K3-K1** K2-K1**	K1FM 1684.00	n.s.
		K1	7.52	1.09	0.94	0.01				
ST (S)	F	K3	4.41	1.16	0.97	0.16			K3FM 1785.00	n.s.
		K2	3.76	0.91	0.15	0.00	29.81	K3-K2** K3-K1**		
		K1	3.17	1.29	0.87	0.00			K2FM 1538.00	**
	M	K3	4.24	0.93	0.96	0.03		K3-K2**		
		K2	2.95	0.90	0.98	0.46	87.54	K3-K1** K2-K1**	K1FM 719.00	**
		K1	2.35	0.69	0.99	0.96				
SD (m)	F	K3	6.79	1.66	0.97	0.19			K3FM 1865.00	n.s.
		K2	5.92	1.48	0.19	0.00	23.02	K3-K2** K3-K1**		
		K1	5.27	1.61	0.97	0.29			K2FM 1085.00	**
	M	K3	6.95	1.53	0.96	0.03		K3-K2**		
		K2	5.15	1.52	0.96	0.07	72.33	K3-K1** K2-K1**	K1FM 954.00	**
		K1	4.23	1.12	0.96	0.09				
T15 (s)	F	K3	8.55	1.03	0.92	0.01			K3FM 95.50	**
		K2	7.86	0.52	0.95	0.01	37.96	K3-K2** K3-K1**		
		K1	7.66	0.63	0.95	0.02			K2FM 790.50	**
	M	K3	7.95	0.70	0.97	0.35		K3-K2**		
		K2	7.09	0.66	0.96	0.02	107.31	K3-K1** K2-K1**	K1FM 1239.00	**
		K1	6.31	0.41	0.97	0.26				
T25 (s)	F	K3	15.10	1.50	0.9	0.00			K3FM 72.50	**
		K2	13.73	1.75	0.53	0.00	39.04	K3-K2** K3-K1**		
		K1	13.67	1.01	0.94	0.01			K2FM 701.00	**
	M	K3	14.02	1.12	0.98	0.23		K3-K2**		
		K2	12.55	0.98	0.96	0.02	110.55	K3-K1** K2-K1**	K1FM 1171.00	**
		K1	11.38	0.65	0.97	0.21				
T50 (s)	F	K3	33.67	3.54	0.91	0.01			K3FM 124.00	**
		K2	30.80	1.90	0.91	0.00	43.47	K3-K2** K3-K1**		
		K1	30.24	2.24	0.95	0.01			K2FM 498.50	**
	M	K3	30.93	2.70	0.97	0.16		K3-K2**		
		K2	27.76	1.88	0.96	0.03	101.94	K3-K1** K2-K1**	K1FM 1074.50	**
		K1	25.56	1.90	0.82	0.00				

Note: M – mean, StD – Standard deviation; BT – block time; FT – flight time; FD – flight distance; UWT – underwater time; UWD – underwater distance; ST – swim time to 15 m; SD – swim distance to 15 m; s – second; m – meter; F – female; M – male; K1-K3 – category the longest UWT. The longest UWD was achieved by the K1 category. Significance of differences (p<0.05; p<0.01) in UWT was evident between the K3-K1 and K3-K2 categories. Significance of differences (p<0.01) in the parameter was evident among all parameters. Inter-sex differences (p<0.01) in UWT were evident in each category. In UWD, inter-sex differences (p<0.05) were evident in K3 and K2 categories (Table 4).

Swim phase

The shortest ST and SD in females were registered in the K1 category. This category also obtained the shortest time in T15, T25 and T50. Significance of differences (p<0.01) was evident in ST between all categories and in SD between K3 and K2-K1. Significance of differences (p<0.01) was evident in T15, T25 and T50 between K3 and K1. In men, results were similar between categories. The shortest ST and SD were registered in the K1 category. The K1 category also achieved the shortest time at T15, T25 and T50. In all parameters in male swim phase, we observed significant differences (p<0.01) between all studied categories. There were no sex differences in K3 categories in ST and SD. In K2 and K1 differences were significant (p<0.01). At T15, T25 and T50, inter-sex differences (p<0.01) were evident in all categories (Table 4).

Discussion

Currently, the swimming rules do not allow for repeated starts. All swimmers start on the starting signal and a swimmer who starts early or makes a move on the starting block before the starting signal is disqualified [31]. Therefore, in swimming and especially in sprint events where hundredths of a second are decisive, it is necessary to have mastered all phases. Improving one phase in the 50 m sprint, or any of the determining parameters, could be decisive for finishing positions or medals [32]. The fastest 50 m freestyle sprint takes approximately 20-21 s for men and 23-23.5 s for women, depending on the length of the pool [33]. From this perspective, it is a very short time duration of the individual phases, where optimisation of the phases is necessary for the best performance. As mentioned above, most of the studies have focused on elite swimmers, while from our point of view, studies should also look at the performance of swimmers in different age categories. The aim of the study is to reveal the differences in kinematic parameters of start and performance in the sprint 50 m freestyle discipline based on gender in different age categories of competitive swimmers at international competitions organized in Slovakia.

Each start begins with a kick start from the starting block and can be characterized as a distance up to 15 m [10, 11]. This phase in swimming is specific and differs from other phases. The swimmer is in the air (the start block phase and the flight phase), where after jumping off the start block, he enters the water. In the phase above the water surface the swimmer's body reaches the highest acceleration. In terms of the percentage of duration of each start phase, the above-water phase contributes the least (12-14%) compared to the underwater phase (41-42%) and the swim phase (44-47%), depending on sex and age category. In general, it can be stated that the underwater and swim phases are more involved in the performance in the start because these phases have a longer duration than the above-water phase. We compare our results with the study by [10], where elite swimmers, Olympic Games and World Championship participants were assessed. The difference was 1% in the proportion of BT, 1% in FT in the above-water phase, 13-14% in the underwater phase, and 16-19% in the swim phase. The differences underwater are mainly due to the longer underwater phase, compared to our research sample, which had a longer swim phase. All these differences were also due to the age categories, as for example in the K1 male and female category the differences were smaller. The difference in K1 females was 2% in the BT, 1% in the FT in the above-water phase, 6% in the underwater phase and 8% in the swim phase. For men, the 1% difference in BT and FT was the same in the above-water phase, and the 14% difference was in the underwater and swim phases.

Performance in kick start, block time was shorter in the K1 category for both sexes, with significance of differences only in females between the youngest K3 and the oldest K1 category. All categories had faster BT (e.g., females K1 0.08s; males 0.04s) than in the study by [10]. The differences could also be due to the readiness of the competitors to perform only one start and not repeated starts as in the study by [10, 34, 35] and others. Also, in other studies [35, 36, 37, 38] where laboratory research on swim starts was conducted, male and female swimmers achieved longer BT. On the other hand, results from the 2016 European Championships also show a longer BT compared to our study [26], where the start conditions were the same as in our study. On the other hand, at the European Championships in Budapest in 2021, both men and women had a faster BT compared to our oldest K1 category [25]. In the above studies, but also in ours, the finding that males achieved faster BT than females were confirmed, although the differences were minimal. We think that behind the faster BT, there may be an increasing number of new OSB start blocks or their imitations every year. In Slovakia, the number of pools where swimmers can perform kick start has increased. It may also help the training process in the start.

In the FT phase of the flight, times in the K1 category for men and women were similar with other studies, either dealing with kinematic analysis in laboratory conditions [10, 34, 35, 39] or directly at the race [2, 25]. The longer duration of male and female FT was also reflected in longer distance in FD, with inter-sex differences ($p<0.01$) demonstrated in every category except the K1 category in FT. The same inter-sex differences in flight phase parameters in the K1 category were found in the [10].

In the underwater phase, our swimmers achieved longer UWT and UWD in the older categories compared to the younger ones ($p<0.05$; $p<0.01$), with males achieving longer UWT and UWD than females. Greater significance of inter-sex differences ($p<0.05$; $p<0.01$) was evident in UWT than UWD. Inter-sex differences were also evident underwater in the butterfly kickers in the study by [20]. At the 2016 and 2021 European Championships, swimmers still achieved slightly longer UWT and UWD compared to our oldest K1 male and female categories. For elite Australian swimmers, the values were even greater [10]. In a study by [39], 4 parameters (FD, average speed between 5 m and 10 m distance, maximum hip depth) were shown to be suitable predictors of optimal gliding that should be addressed by coaches and swimmers. In the swim phase, the older categories achieved shorter ST and SD, with males achieving shorter values ($p<0.01$) than females, except for inter-sex differences in the K3 category. The T15, T25 and T50 performances were achieved with shorter times in the older K1 categories, with inter-sex differences ($p<0.01$) in favour of males in all categories. Other studies [2, 10, 25] have also confirmed inter-sex differences. In a comparison of start times between the 100 m swimming modes at the 2016 European Championships, men achieved shorter start times in the butterfly compared to the freestyle, with no significance of differences confirmed. The women had the fastest start in the freestyle and then in the butterfly. The significance of the differences between freestyle and butterfly was not confirmed here either. Similar values were also measured at the European Championships in 2021. However, in the T25 and T50 the values were already in favour of the freestyle over the butterfly for both sexes [25].

To optimize the kick start in the 50 m freestyle discipline, it is currently necessary to use available methods, such as a camera system, which can be used to evaluate the above and underwater phases and the swim phases individually (depending on age and gender) and thus get relevant information about the start and performance that can be used to adjust the correct training, which can result in an improvement of the 50 m freestyle time.

Conclusions

Evaluating the kinematic analysis of the sprinters' starts directly from the race can help not only coaches but also swimmers in each category. An important part of the evaluation is the inter-sex differences. In terms of the percentage of each phase at the start in the men's and women's 50m freestyle, the underwater phase and the swim versus the above-water phase proved to be longer lasting. In the above-water phase, we found significant differences ($p<0.01$) especially between the K3-K1 categories in the FD, as well as inter-sex differences. The results suggest that we recommend performing this phase separately.

Similar findings were in the underwater phase. We recommend coaches to lead the underwater training process based on age categories and gender. The reason for this recommendation is that the oldest K1 category achieved longer UWT and UWD compared to the youngest K3. In the swim phase, we observed the largest differences ($p<0.01$) between the K3-K1 category in both males and females, therefore we do not recommend a shared training process for this phase. In contrast, there were no significant inter-sex differences in the K3 category, therefore we think that this category could perform this phase together.

Significant differences were also evident at T15, T25 and T50 between all categories and gender. The largest differences ($p<0.01$) were again between the K3-K1 categories for both males and females, so here again the training process should be approached separately.

All the above differences of swimmers are to some extent caused by sport age in each category, gender differences, technical level, etc. Based on the above results, we recommend approaching the improvement of start and performance in 50 m freestyle separately using kinematic analysis, which will allow to optimize the performance.

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