KINEMATICAL COMPARISON OF 50 METERS BUTTERFLY RACE COMPONENTS OF PAKISTANI AND INTERNATIONAL SWIMMERS

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ABSTRACT: *Present study presents the kinematic analysis of race components (RCs) between male swimmers (n=8) participated in European Swimming Championship, 2012 held at Debrecen, Hungary and male swimmers (n=24) from National Swimming Championship 2014 held at Islamabad, Pakistan. For 50 meters Butterfly event, Race components (RCs) of Pakistani swimmers were monitored with digital video cameras installed at distance (m) 5, 15, 25 and 45 from starting point. Total Race time (RT) was divided into six race components (RCs) i.e. Surface Break Point (SBP), Starting Time (ST), Split Time 25 (ST_1), Split Time 45 (ST_2), Stroking Time (CT) and Finishing Time (FT). The correlation of RT with ST_2 and CT was significant at $p<0.01$ and with ST_1 at $p<0.05$. The comparison between Pakistani and International swimmers, by applying t-test and ANOVA revealed a significant ($p<0.01$) difference in mean times of all RCs as well as average velocity ($0.41 ms^{-1}$). The prediction models for ST_1, ST_2 and CT for Pakistani swimmers on the basis of RT were significant ($R^2 \geq 0.67$, $p<0.01$). The average velocity of Pakistani swimmers was 1.72 ± 0.08 ms^{-1} that was 0.41 ms^{-1} less than the international swimmers. The results can be used as a benchmark to allow top level Pakistani swimmers and their coaches to identify weak race components for focused training.*

Keywords: *50 meters Butterfly, Kinematic, Race Components, Race Time*.

INTRODUCTION

In swimming, a fundamental requirement for best performance is to capture, analyze and evaluate information on key areas such as the vital portions of a race event. Such information on numerous characteristics is the foundation for providing feedback that how a swimmer is performing. This feedback leads to the development of scientific coaching interventions centered on evidence-based practice within daily training and preparation for competition. When the opinions, experiences and know-how of elite practitioners are supplemented with these scientific coaching methods; this integrated approach may prove critical in finding that extra margin between success and failure [1,2]. For example [3] carried out a study on analysis of race time (RT) of competitive swimmers. They divided the race time into four parts named Race Components (RCs), i.e., the time spent in starting (ST), the time spent in stroking (CT), the time spent in turning (TT) and the time spent in finishing (FT).

Kinematical comparison analysis is currently a common practice for major swimming championships. Prior to the conductance of such analysis, the coaches had to rely on lap splits and finishing times to objectively assess the performance of athletes under given directions [4,5]. Such competition analyses provide the information to coaches regarding comparative data of swimmers' performance with respect to the starting time, free swimming time, turns and also the finishing time [6,7]. Depending upon the reliability the data processing and analysis, the coaches can establish strengths and weaknesses of swimmers throughout the race a at much higher confidence level [8]. It has now become a common ritual to perform biomechanical analysis of data obtained from major swimming championships and Olympic events. Significant correlations between key swimming elements and finishing times are very critical and the coaches can have a keen focus on these vital variables. [9] analyzed sixteen swimmers' performances obtained during World Swimming Championships conducted in Rome. They reported that for most of the events, average velocity had a very high correlation (r = 0.9 at p 0.001) with resulting time.

Sports researchers have been studying these race components of competitive swimmers in different countries, over the period of time. For examples, [10] in Spain, [11] in Sydney 2000 Olympic Games Australia, [12] in China used the videos and performed the component analysis. They stressed upon the importance of RCs and their analysis. Further, they used different kinematical approaches to compare them with other elite swimmers. It has also been highlighted by them to formulate swimmers' training programs in view of the study of RCs [10,13].

A comprehensive study was conducted by [14] on performance comparison of swimmers participated in World Championships from 1994 to 2013 and Olympic Games from 1992 to 2012 using different techniques including multi-level regression analysis. They showed that young swimmers benefit from training in longer race distances (200 m and above) before they change to shorter distances (50 m and 100 m).

Analyzed the fastest butterfly swim ever made by Ukraine´s Andriy Govorov in the semi-finals of the Men's 50 m butterfly swimming event at the Euro Championship, 2016[15]. Race event was divided into 3 components i.e. Starting, Clean Swimming and Finishing [15]. The start represented 24%, the stroking (or clean swim) 65% and the finish 11% of the total race time for the athlete [15].

In an elite swimming competition during World Championship or a National Championship, number of cameras are usually installed at the site in various positions at regular intervals to record every dive, stroke and splash in the pool [16,17]. This recording is subsequently used by the coaches and swimmers to measure and analyze every aspect of performance from the length of a dive to the underwater spent time to the peak velocity that a swimmer attained during the race. The

analysis of these videos helps in making a qualitative judgment on performance of swimmer and areas of improvement or areas which have been weakened to be identified [18]. For example, with an aim to increase efficiency and speed by minimizing the number of strokes per length in a race, an athlete may be focusing on increasing the distance covered in each stroke. The video analysis allows athletes and coaches to assess whether this technique is beneficial. Moreover, a comparison of recent training sessions can also be made with the swimmer's best performance. This type of analysis helps in evaluating each section of the race, enabling coaches and swimmers to observe any desired improvement in a section [17].

Materials and Methods

Twenty-four Pakistani male swimmers who qualified for the finals of National Swimming Championship 2014 held at Islamabad, Pakistan and eight international male finalist swimmers, participated in European Swimming Championship 2012 in butterfly event were included in this study. All the visuals of the event were recorded with four digital cameras (Sony HDR-HC9E) and the videos were synchronized with the official timing given by Omega. All the distances were recorded from the perpendicular plane of the swimmer's position at a distance of 6 meters from the pool [18] 18-(Morales *et al.*, 2010). Cameras were positioned at 5, 15, 25 and 45m from the starting point. The Pakistani swimmers' data was compared with the data obtained 9. .

from the website [http://swim.ee] for European Swimming Championship 2012 finalists (n=8). A software Kinovea was used to calculate/analyze race components from videos imposing digital lines on the video playback at 15, 25 and 45 m with the help of pool side eight calibration marks [19]. The analysis of data with help of the software provided time values for following eight Race Components [20].

1. Surface Break-Point Time (SBP) – time (sec) at which a swimmer head breaks surface of water from starting of race.
2. Starting Time (ST) – time (sec) at which the head of swimmer passes through 15meters interpolated line from starting of race.
3. Split Time 25m (ST_1) – time (sec) at which the head of swimmer passes through 25 meters interpolated line from 15 meters mark.
4. Split Time 45m (ST_2) – time (sec) at which the head of swimmer passes through 45 meters interpolated line from 25 meters mark.
5. Stroking Time (ST_3) – time (sec) at which the head of swimmer passes through 45 meters interpolated line from 15 meters mark.
6. Finishing Time (FT) – time (sec) taken by swimmer from 45 meters interpolated line to finishing line.
7. Race Time (RT) – time (sec) taken by swimmer from starting of race to finishing line.
8. Average Velocity (AV)ms^{-1}: The value obtained by dividing the total distance (50m) by RT

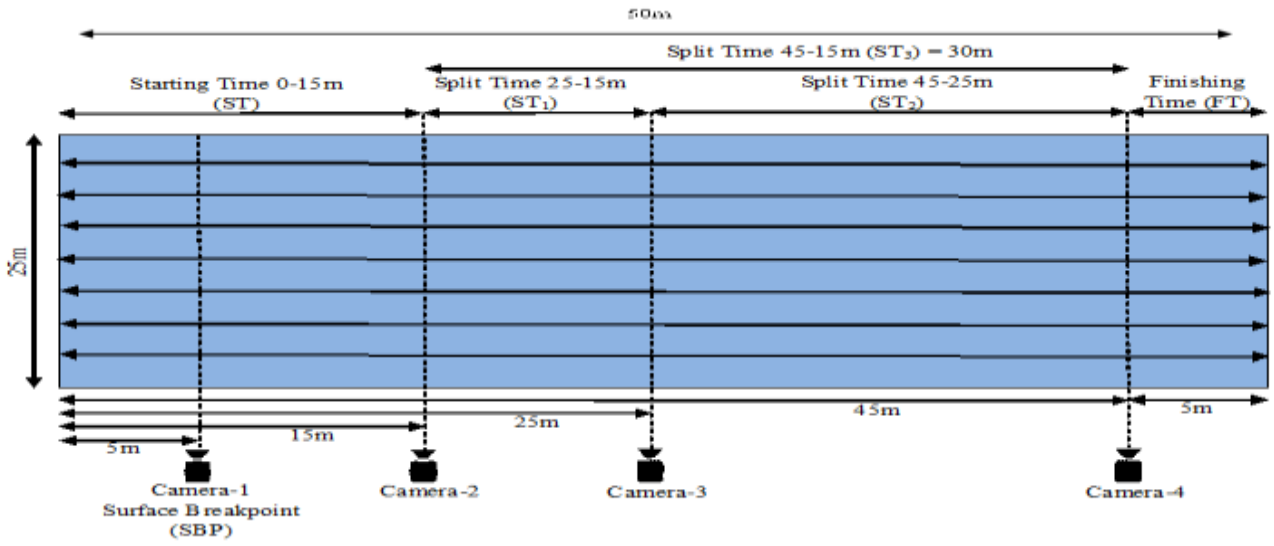

Fig. 1: Camera installations at 5, 15, 25 and 45m distance and Race Components on 50m swimming pool

Statistical Analysis

Kolmogorov-Smirnov test ($\alpha = 0.05$) was applied [21] to check the normality of the data. Statistical Analysis were carried out by using SPSS 19.0 statistical software (SPSS Inc., Chicago, III., USA.). For testing of hypothesis, different levels of significance (α=0.05, 0.01, 0.001) were used.

RESULTS DISCUSSIONS

The mean times showed that the Pakistani swimmers took more time for all variables as compared to the international swimmers except for SBP. The S.D. indicated that Pakistani Swimmers were less consistent than international swimmers at all RCs except SBP. Results showed that larger the distance covered during the race, higher the S.D. A huge variation was found among the performance of Pakistani swimmers. Coefficients of skewness for Pakistani swimmers showed that the distribution of the SBP was negatively skewed while ST, ST_1 ST_2, CT and RT were positively skewed. The distribution of AV was also negatively skewed. The

distribution of SBP, ST ST_1, and FT of international swimmers was negatively skewed while it was positive for ST_2, CT and RT. Skewness trend for Pakistani and international swimmers was same for SBP, ST_2, CT and RT but it was different for ST, ST_1, FT and AV. Average velocity (AV) of Pakistani swimmers was 1.72 ms^{-1} which was 0.41 ms^{-1} less than international swimmers.

Table 1: Descriptive Analysis of Race Components (RCs) of 50 m butterfly male swimmers (n=24) from National Swimming Championship, 2014 held in Islamabad, Pakistan and finalist male swimmers (n=8) of European Swimming Championship, 2012 held in Debrecen, Hungary.

Race Components	Pakistan				International			
	Time (sec.)			Skewness	Time (sec.)			Skewness
	Min.	Max.	Means		Min.	Max.	Means	
SBP	2.27	3.97	3.23±.52	-0.49	3.42	5.26	4.77±.62	-1.69
ST	6.80	8.00	7.29±.36	0.90	5.36	5.88	5.63±.19	-0.08
ST_1	5.52	6.28	5.79±.31	1.06	4.90	5.20	5.06±.09	-0.45
ST_2	12.38	14.55	12.94±.68	2.27	10.28	10.80	10.42±.16	2.22
CT	17.90	20.79	18.73±.91	1.98	15.22	15.88	15.48±.20	1.19
FT	2.51	3.95	3.03±.44	1.25	2.28	2.43	2.36±.05	-0.58
RT	27.41	32.00	29.05±1.41	1.37	23.16	23.80	23.47±.20	0.19
AV(ms^{-1})	1.56	1.82	1.72±.08	-1.21	2.10	2.16	2.13±.02	0.22

SBP = Surface Breakpoint, ST = Starting Time 0-15 m, ST_1 = Split Time 15-25m, ST_2 = Split Time 25-45 m, CT = Stroking Time 15-45 m, FT = Finishing Time 45-50 m, RT = Race Time, AV=Average velocity.

Correlation Matrix

The Table 2 indicated that all the RCs of Pakistani swimmers were positively correlated with RT except SBP. The correlation of RT was significant with ST_1 ($p<0.05$), ST_2 ($p<0.01$) and CT ($p<0.01$). The relationship of SBP with all other RCs was insignificant ($p>0.05$) except ST_2 and CT. The relationship of SBP with ST_2 and CT was significant ($p<0.05$). The ST had insignificant ($p>0.05$) but positive correlation with ST_1, ST_2 and CT except for FT. The correlation of ST was significant with ST_2 ($p<0.05$). The correlation of ST_1 was significant with CT and FT ($p<0.05$). The relationship of ST_2 was significant ($p<0.01$) with CT but insignificant with FT. CT and RT were highly correlated ($r = 0.98$) with each other.

It is also evident from the data that the correlation coefficients of RCs of international swimmers with RT were not similar as Pakistani swimmers. The RT of international swimmers insignificantly correlated with all others RCs except ST_2 ($p<0.05$). The SBP had a negative correlation with ST, ST_2 and FT except for ST_1 and CT. The SBP was only significant ($p<0.05$) with ST. The correlation of SBP with ST and FT of Pakistani and international swimmers was almost the same but there was a big difference with ST_1, ST_2 and CT. The correlation of ST was inversely significant ($p<0.01$) with ST_1. The correlation of ST_1 with ST_2, CT and FT were insignificant. The correlation of ST_2 and CT was significant ($p<0.01$). The relationship of CT with FT was insignificant for both Pakistani and international swimmers.

Table 2: Correlation Matrix of 50 m butterfly RCs of male national swimmers (n=24) and male international swimmers (n=8).

Race Components	SBP	ST	ST_1	ST_2	CT	FT	RT
Pakistan							
SBP	1	-0.38	-0.58	0.71*	-0.73*	-0.31	-0.66
ST		1	0.17	0.80*	0.66	-0.1	0.65
ST_1			1	0.65	0.82*	0.77*	0.82*
ST_2				1	0.97**	0.37	0.94**
CT					1	0.53	0.98**
FT						1	0.64
RT							1
International							
SBP	1	-0.55	0.75 *	-0.15	0.20	-0.22	-0.38
ST		1	-0.87**	-.015	-.38	0.18	0.60
ST_1			1	0.23	0.61	-0.30	-0.29
ST_2				1	0.91**	-0.51	0.73*
CT					1	-0.55	0.48
FT						1	-.11
RT							1

Average Velocities (AV)

It was evident from Fig. 2 that average velocity of international swimmers was considerably high at start of the race. The velocity of Pakistani swimmers was 2.1 ms^{-1} at the start which was reduced to 1.7 ms^{-1} as they crossed mid of the pool. This velocity was further decreased to 1.5 ms^{-1} as the athletes passed 45 m mark and then they maintained this velocity in the finishing phase during the last 5 m of the race. However, the international swimmers had an excellent start with an average velocity of 2.7 ms^{-1}. The velocity dropped to 2.0 ms^{-1} as they crossed mid of pool. From mid of the pool to the end they successfully managed to keep this velocity constant.

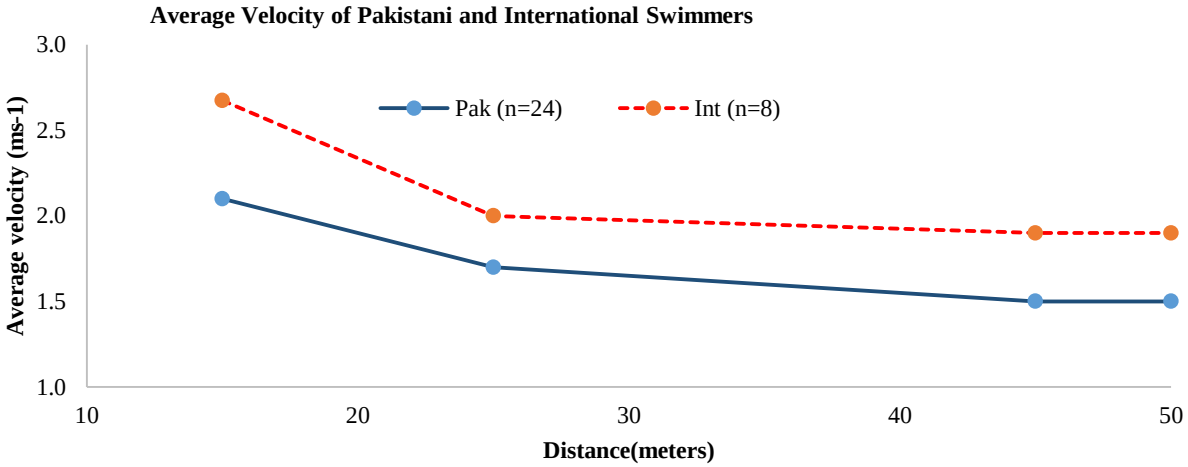

Fig. 2: Comparison of Average Velocity of 50m butterfly for different distances for finalist male international swimmers (n=8) and male national swimmers (n=24).

Race Components (RCs)

The analysis of 50 m butterfly event revealed variation in the differences between race components of national and international swimmers. The completion times for all RCs of international swimmers were lower than Pakistani swimmers except SBP. Mean time of SBP of international athletes was 1.54 seconds higher while the difference in respectively. Starting Time (ST) was 1.66 seconds. Comparison of Split time (ST_2) 25-45 m and Stroking time (CT) 15-45 m depicted that there was a significant difference in time i.e. 2.52 and 3.25 seconds respectively. In Split time (ST_1) 15-25 m and Finishing Time (FT) the difference was 0.73 and 0.67 seconds

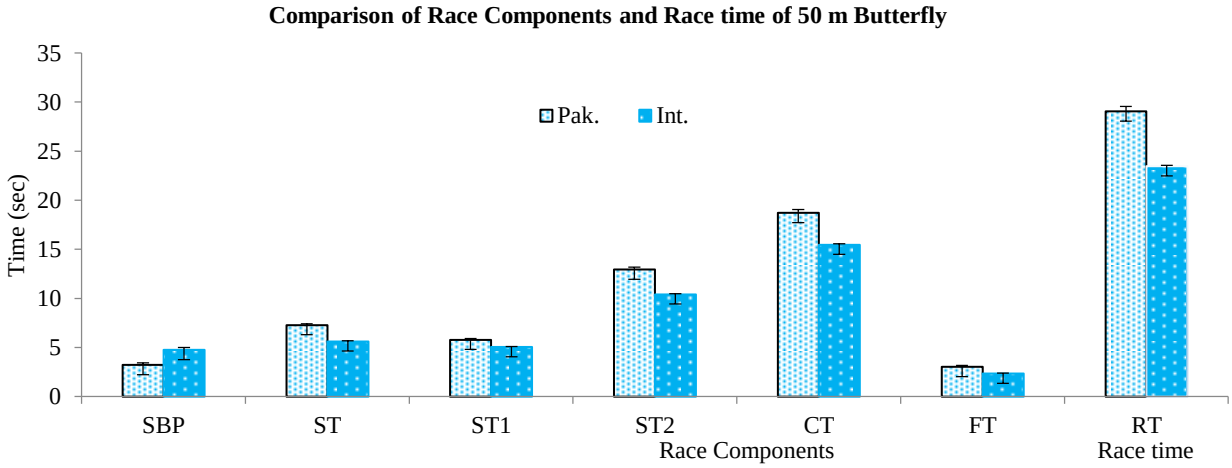

Fig. 3: Race Components (mean time ± S.E.) of male international swimmers (n=8) and male national swimmers (n=24).

Comparison of Race Components Mean Time (Independent t-test)

The Table 4 showed the results of t-test for independent variables with unequal sample sizes. Mean times, difference of mean times, Standard error (S.E.), t-value and p-values were calculated for SBP, ST, ST_1, ST_2, CT, FT, RT and AV for both Pakistani and international swimmers. The t and p values for all variables showed that there were significant mean differences between Pakistani and international swimmers. The results further indicated that SBP, ST, ST_1, ST_2, CT, RT and AV had highly significant differences ($p<0.001$) except FT ($p<0.01$). Results indicated that the performance of Pakistani swimmers was very disappointing for all variables. The values of S.E. for Pakistani swimmers were larger in all cases except SBP than the S.E. of international swimmers. This showed that Pakistani swimmers were not consistent in their performance as compared to international swimmers

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Table 4: T-test for independent samples of 50 m butterfly male national swimmers (n=24) and male international swimmers (n=8) (with unequal sizes and variances).

Race Components	Mean Time (sec)		Difference (sec.)	S.E.		t-values	P-values
	Pak.	Int.		Pak.	Int.		
SBP	3.23	4.77	-1.54	0.19	0.22	-5.30	***
ST	7.29	5.63	1.66	0.13	0.07	11.62	***
ST_1	5.79	5.06	0.73	0.11	0.03	6.45	***
ST_2	12.94	10.42	2.52	0.24	0.06	10.64	***
CT	18.73	15.48	3.25	0.32	0.07	9.84	***
FT	3.03	2.36	0.67	0.15	0.02	4.20	**
RT	29.05	23.47	5.58	0.50	0.07	11.07	***
AV(ms^{-1})	$1.72ms^{-1}$	$2.13ms^{-1}$	-0.41 ms^{-1}	0.03	0.01	-13.99	***

**Significant (p<0.01), ***Significant (p<0.001)

Regression Analysis

The values of R^2 for prediction models of SBP, ST and FT were 0.44, 0.42 and 0.40 respectively. These values, being less than 0.50, showed that the models for SBP, ST and FT were not good fit. The F and p-values for models of SBP, ST and FT also indicated that these models were insignificant (p>0.05). The values of R^2 for ST_1 (0.67), ST_2 (0.89) and CT (0.96) indicated that these models are best fit. These values also indicated that 67%, 89%, and 96% variation in ST_1, ST_2, and CT respectively could be explained by RT. The prediction models for ST_2 and CT were highly significant (p<0.001) while the model for ST_1 was also significant (p<0.01). It was noted that the values of S.E. for ST, ST_2 and CT were very low which indicated that the values of prediction models were adequate .

Table 5: Simple Linear Regression Estimates and ANOVA for prediction of male swimmers (n=24) from National Swimming Championship 2012 held at Islamabad, Pakistan.

Prediction Models	R^2	S.E.	F	P-Values
SBP = 10.42 - 0.25 RT	0.44	0.42	4.75	ns
ST= 2.53 + 0.16 RT	0.42	0.29	4.37	ns
ST_1= 0.61 + 0.18 RT	0.67	0.19	12.02	**
ST_2= -0.35 + 0.46 RT	0.89	0.24	48.86	***
CT= 0.26 + 0.64 RT	0.96	0.18	161.08	***
FT= - 2.79 + 2 RT	0.40	0.37	4.06	ns

Predictors: (Constant), Race Time (RT) in seconds.

**Significant (p<0.01), ***Significant (p<0.001)

CONCLUSION:

Average velocity (AV) of Pakistani swimmers was 1.72 ms^{-1} and was 0.41 ms^{-1} (24%) less than international swimmers. The mean race time of Pakistani swimmers (n=24), in this study, was 29.05±1.41 seconds which was about 5.58 seconds slower than international athletes studied in this research. Stroking time (CT) for butterfly event was 18.73±0.91 and 15.48±2 seconds for local and international swimmers respectively with a difference of only 3.25 seconds. The difference between finishing time (FT) was 0.67 seconds. Comparison of Split time 25-45 m (ST_2) and stroking time 15-45 m (CT) showed that there was a significant difference of 2.52 and 3.25 seconds between local and international swimmers, respectively. In Split time 15-25 m (ST_1) the difference, between local and international swimmers was only 0.73 seconds showing that the difference in time increased as the race progressed. These models can be used for top level Pakistani swimmers and their coaches to find out weak race components for focused training.

REFERENCE:

1. Hannula, D. and Thornton, N. (2012). Better Starts, Turns, and Finishes. In, "*The Swim Coaching Bible*." (Vol. II, pp. 210-221). Champaign, IL: Human Kinetics.
2. Bay, S. (2016). Turns. In, *"Swimming: steps to success: learn and master basic strokes, starts, and other aquatic skills."* (pp. 175-200). Champaign, IL: Human Kinetics.
3. Pai, Y.C., Hay, j. G., and Willson, B.D. (1984). Stroking Techniques of Elite Swimmers. *Journal of Sports Sciences*, ***2*(3)**: 225-239.
4. Hudson, C. (2014). Inter-analyst variability in swimming competition analysis. *Procedia Engineering*, ***72***: 192-195.
5. Vantorre, J., Chollet, D., and Seifert, L. (2014). Biomechanical Analysis of the Swim-Start: A Review. *Journal of Sports Science and Medicine*, ***13(2)***: 223-231.
6. Smith, W. (2002). The Secret of Ian Thorpe's Blistering Speed, Courier Mail, 2002, April 1.Http://www.limmatsharks.com/IanThorpe/. Google Scholar
7. Suito, H., Nunome, H., and Ikegami, Y. (2016,). Relationship Between 100-m Race Times and Start, Stroke, Turn, Finish Phases at the Freestyle Japanese Swimmers. In, "*33rd International Conference of Biomechanics in Sports, Conference Proceedings Archive*." ***33(1)*:** 1224-

1227.
8. Tor, E., Pease, D., and Ball, K. (2014). Characteristics of an elite swimming start. In, *"XII International Symposium on Biomechanics and Medicine in Swimming."* (Vol. 1, pp. 257-263). Canberra: Australian Institute of Sport.
9. Mason, B. R., Loschner, C., and Fowlie, J. (1995). Competition Analysis at the World Swimming Championships. In, "*13th International Symposium on Biomechanics in Sports."* Thunder Bay, Ontario: Canada.
10. Morales, E., Arellano, R., Femia, P., Mercade, J., and Haljand, R. (2010). 50m Race Components Times Analysis Based on a Regression Analysis Model Applied to Age- Group Swimmers. In, *"XIth International Symposium for Biomechanics and Medicine in Swimming."* P.L. Kjendlie, R.K. Stallman and J. Cabri (Eds.). pp 127-129. Oslo: Norwegian School of Sport Sciences.
11. Arellano, R., Cossor, J., Wilson, B., Chatard, J., Riewald, S., and Mason, B. (2001). Modelling competitive swimming in different strokes and distances upon regression analysis: A study of the female participants of Sydney 2000 Olympic Games. In, *"19th International Symposium on Biomechanics in Sports." Proceedings Archive* ***1*****(1)**: 53–56.
12. Du, G., and Xiong, C. (2013). Statistic and Evaluation of Data Between Chinese and Foreign Female Freestyle Swimmers in Long Distances. In, "*Informatics and Management Science VI.*" (pp. 693–699). London: Springer.
13. Arellano, R. (2010). Interpreting and Implementing the Long-Term Athlete Development Model: English Swimming Coaches' Views on the (Swimming) LTAD in Practice a Commentary. *International journal of Sports Science & Coaching*, ***5*****(3)**: 413-419.
14. Knechtle, B., Bragazzi, N., König, S., Nikolaidis, P., Wild, S., Rosemann, T., and Rüst, C. (2016). The Age in Swimming of Champions in World Championships (1994– 2013) and Olympic Games (1992–2012): A Cross-Sectional Data Analysis. *Sports*, ***4*****(1)**:17.
15. Barbosa, T. M. (2016). Fastest Butterfly Swim Race Analysis: M50Fly by Ukraine´s Andriy Govorov at 2016 Euro Champs. Retrieved March 15, 2017, *from* *http://www.swimmingscience.net/fastest-butterfly-swim-race-analysis-m50fly-ukraines-andriy-govorov-2016-euro-champs*.
16. Smith, D. J., Esau, S., Norris, S. R., and Bidrmann, J. (2002). A Case Study of Swimming Competition Analysis and Training Leading to an Olympic Final. *Medicine & Science in Sports & Exercise*, ***34*****(5)**: 76.
17. Mooney, R., Corley, G., Godfrey, A., Osborough, C., Newell, J., Quinlan, L. R., and ÓLaighin, G. (2016). Analysis of swimming performance: perceptions and practices of US-based swimming coaches. *Journal of Sports Sciences*, ***34*****(11)**: 997-1005.
18. Mooney, R., Corley, G., Godfrey, A., Osborough, C., Quinlan, L. R., and Ó Laighin, G. (2015). Application of video-based methods for competitive swimming analysis: a systematic review. *Sports and Exercise Medicine*, ***1*****(5)**: 133-150.
19. Nazeer, M. T., Akhtar, T., Nawaz, U. and Mayo, Z. A. (2016). Comparison of 50 Meters Freestyle Race Component Time Analyses of Pakistani and International Swimmers. *Science International*, ***28*****(2)**: 1205-12011.
20. Arellano, R. (2004). Applying biomechanical testing to swimming training. In, *"European Seminar on Swimming Coaches*." Madrid.
21. Mooney, R., Quinlan, L. R., Corley, G., Godfrey, A., Osborough, C., and ÓLaighin, G. (2017). Evaluation of the Finis Swimsense® and the Garmin Swim™ activity monitors for swimming performance and stroke kinematics analysis. *PloS one*, ***12*****(2)**: e0170902

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