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Analysis and Prediction of Race Components of Pakistani and International Swimmers

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Abstract- Kinematical analyses were carried out for race components (RCs) of Pakistani and International 100m freestyle male swimmers to identify the weakness and strengths of local swimmers. RCs and Average Speed of Pakistani swimmers were recorded and analysed with six HD video cameras installed at 5, 15, 25, 35, 40 and 45 m distance from start. Results revealed that ST3, ST4 and CT2 were significantly correlated to RT for Pakistani swimmers. Significant difference was found in all RCs and average speed of Pakistani and International swimmers. The prediction models for ST3, ST4, and CT2 were highly significant ($p<0.001$) and also best fit because values of R2 were 0.95, 0.89, and 0.97 respectively. Results revealed that Pakistani swimmers were far behind than their international counterparts. Coaches and elite swimmers of Pakistan can improve race components' times by using these results and prediction models.

Keywords: **MODELLING, RACE COMPONENTS, FREESTYLE, SWIMMING**

I. Introduction

Science can maximize potential and help in the fine tune of athlete, making small improvements in the swimmer's performance, which is often significant as just a few hundredths of a second can decide the result of races. In modern times, races are not won by the swimmer in elite swim competitions, getting out and giving it all they have. Races are won by careful preparation which involves developing a good game plan or competition model for the swimmer concerned and this is where the biomechanics comes in (Mason, 2017). To achieve the best performance, it is important to capture, analyse and evaluate the data of a racing event. Competition analysis can best be used to identify where a swimmer's weaknesses exist. A swimmer's weaknesses or inefficiencies can be identified by examining the competition analysis of the swimmer's performance in comparison to that of swimmers of roughly equal ability. Coaches can prioritize the area of weakness in their trainings with the help of comparison data.

Total race time offers inadequate data regarding swimmers' performance. For detailed information, a race is divided into different parts called Race Components (RCs) e.g. Starting Time (ST), Stroking Time (CT), Turning Time (TT) and Finishing Time (FT). Race components time also have a critical importance as well as total race time (Arellano Colomina et al., 2016; Veiga & Roig, 2016). Weakness of a swimmer may exist in any race component i.e. starting, turning, finishing or stroking (Bruce Mason, 1999). Once a weakness is identified, the swimmer's race model may be altered by coach to develop a better race plan. The coach then needs to train the swimmer to new competition model (Bruce Mason & Cossor, 2000).

Previous studies highlighted the importance of study of Race Components (RCs) and its application to identify weakness of a swimmer; specific training for the weakness can enhance the performance of swimmer (Veiga et al., 2014 and Mason and Cossor, 2000). The study of RCs may be used for prediction of each race component relative to race time. Arellano et al., (1996) used regression analysis to develop mathematical model of race components for swimmers participated in Sydney Olympic Games 1992. The mathematical models provided RCs in the form of the percentage of total race time. Mathematical models can be used to calculate recommended times for each race components (RCs) in relation to total race time (RT). These equations provide coaches and swimmers a clear target to improve their swimming time (Przednowek et al., 2016; Wiktorowicz et al., 2015). From a coach's point of view, the prediction of results is very important in the training process. A model of race components of elite swimmers can serve as a reference for coaches to train the upcoming swimmers.

The aim of this study was to compute race components (RCs) times of competitive swimmers of Pakistan by recording national competitions, compare these RCs times with international swimmers' timing to find out strengths and weaknesses of Pakistani swimmers and develop mathematical models for prediction of RCs times that can be used for national swimmers.

II. Material and Method

Twenty-four Pakistani male semi-finalist swimmers of National Swimming Championship 2014 and eight 100m freestyle event finalist of the European Swimming Championship 2012 were subjects of study. Data for Pakistani swimmers was recorded during competition and data for International swimmers was taken from www.swim.ee on 19-09-2014.

100m freestyle race was divided into ten race components on the basis of time taken by swimmers to cover that particular distance i.e. Starting Time (ST) from start to 15m, Split Time 1 (ST_1) from 15m to 25m, Split Time 2 (ST_2) from 25m to 45m, Stroking Time 1 (CT_1) from 15m to 45m, Turning Time (TT) from 45m to 60m (5+10m), Split Time 3 (ST_3) from 65m to 75m, Split Time 4 (ST_4) from 75m to 95m, Stroking Time 2 (CT_2) from 65m to 95m and Finishing Time (FT) from 95m to finishing of the race. Surface Break-Point (SBP) is the time (sec) from start of race to the point from where head of swimmers come out of surface of water. Time (RT) and Average Speed (AS) were also used for analysis.

Videos of Local Swimmers were recorded by installing six cameras (SONY CMOS Digital - HDR-HC9E, 29fps) along the axes of markers placed at 5, 15, 25, 35 (for 65m), 40 (for 60m) and 45 m respectively following the procedure described by Morales et al., 2010. A specialized motion analysis software (Kinovea: 0.8.15) was used to for the calculation of race components from the video recordings (Bacic & Hume, 2012). Correlation was used to find the relation of total race time with race components (RCs). To compare the performance of Local and International swimmers at different race segment, Independent sample t-Test was used. Simple linear regression was used to develop mathematical models. SPSS (22.0; SPSS, Inc., Chicago, IL) was used to carry out all statistical analyses and significance value was at $p < 0.05$.

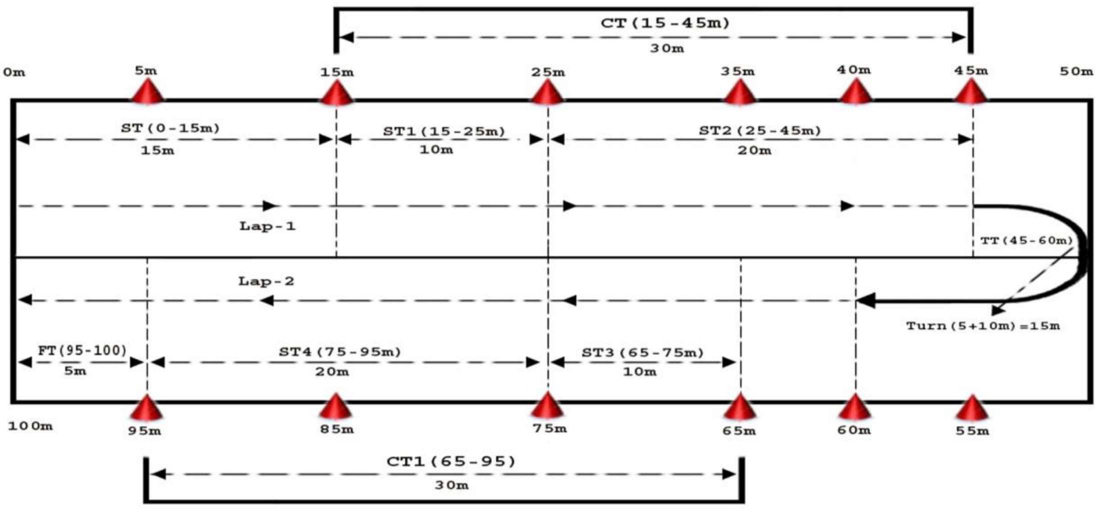

Figure 1: Race components of 100m Freestyle

III. Results

Results indicated that the correlation of RCs of Pakistani swimmers was positive with RT except SBP, ST_1 and CT_1. The RT was significantly correlated ($p<0.01$) with ST_3, ST_4 and CT_2. All RCs did not reveal similar trend in association to the RCs of international swimmers.

Table 1. Correlation of RCs with RT and independent samples t-test for 100 m Freestyle male swimmers.

RCs	Correlation With RT		Mean Time±S.D		Diff. (S)	S.E		t-values	P-values
	Pak	Int	Pak	Int		Pak	Int		
SBP	-.16	.65	2.78±0.32	3.86±0.49	-1.08	0.11	0.17	-5.23	.000***

ST	.26	-.25	7.23±0.41	5.69±0.22	1.54	0.14	0.08	9.45	.000***
ST₁	-.17	.30	5.43±0.23	4.92±0.12	0.51	0.08	0.04	5.50	.000***
ST2	.37	-.04	12.14±0.05	10.10±0.13	2.04	0.02	0.05	41.29	.000***
CT1	-.10	.15	17.56±0.19	15.02±0.21	2.55	0.07	0.08	25.55	.000***
TT	.53	.41	8.14±0.31	7.03±0.12	1.12	0.11	0.04	9.49	.000***
ST3	.98**	.36	8.34±1.34	5.25±0.05	3.09	0.47	0.02	6.52	.000***
ST4	.94**	.37	14.97±1.49	11.03±0.27	3.94	0.53	0.09	7.36	.000***
CT2	.99**	.40	23.31±2.75	16.28±0.30	7.03	0.97	0.11	7.19	.000***
FT	.56	.10	3.18±0.17	2.53±0.07	0.65	0.06	0.03	10.12	.000***
RT	1	1	61.61±3.24	49.12±0.19	12.49	1.15	0.07	10.87	.000***
AS	-	-	1.63±0.08	2.03±0.01	-0.41	0.03	0.00	-13.5	.000***

Mean differences between Pakistani and international swimmers were significant as revealed from p and t values. All variables had high significant ($p<0.001$) differences which is depicted in Figure 2.

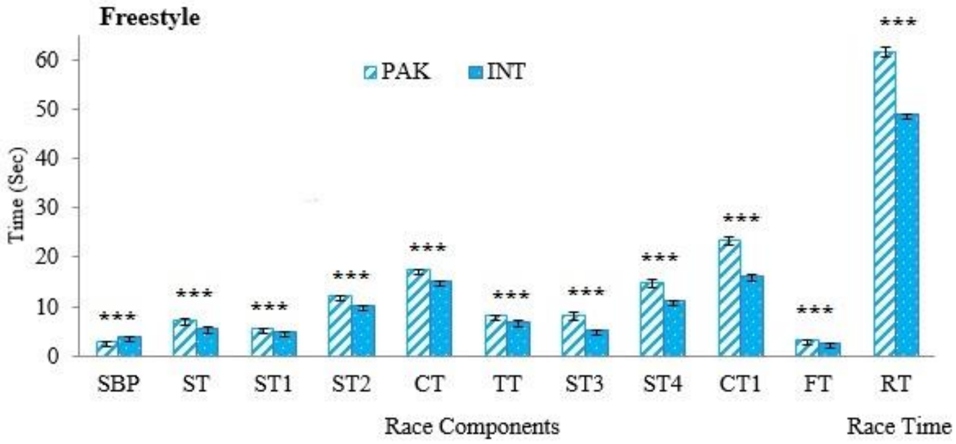

Figure 2: **Independent sample t-test for Pakistani and International Swimmers**

Partial contribution (%) was similar in ST (12%) for both. However, different ratios of contribution in CT_1 (30%: 32%), TT (14%,15%), CT_2 (39%,35%) and FT (5%,6%) were observed with respect to RT.

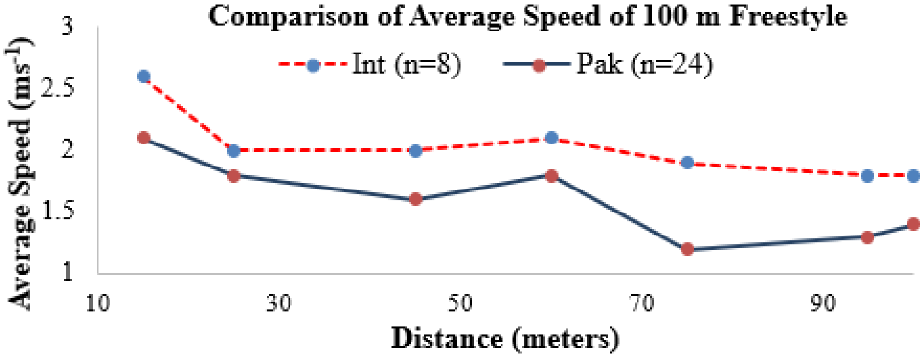

Figure 3: Comparison of Average Speed of 100 m Freestyle for different distances of Pakistani and international swimmers

The Figure 3 showed that RT had a positive and linear trend with CT_2, ST_3, and ST_4. While RT had a positive trend with FT, TT and ST_2, the relationship between RT with SBP, CT_1 and ST_1 was negative.

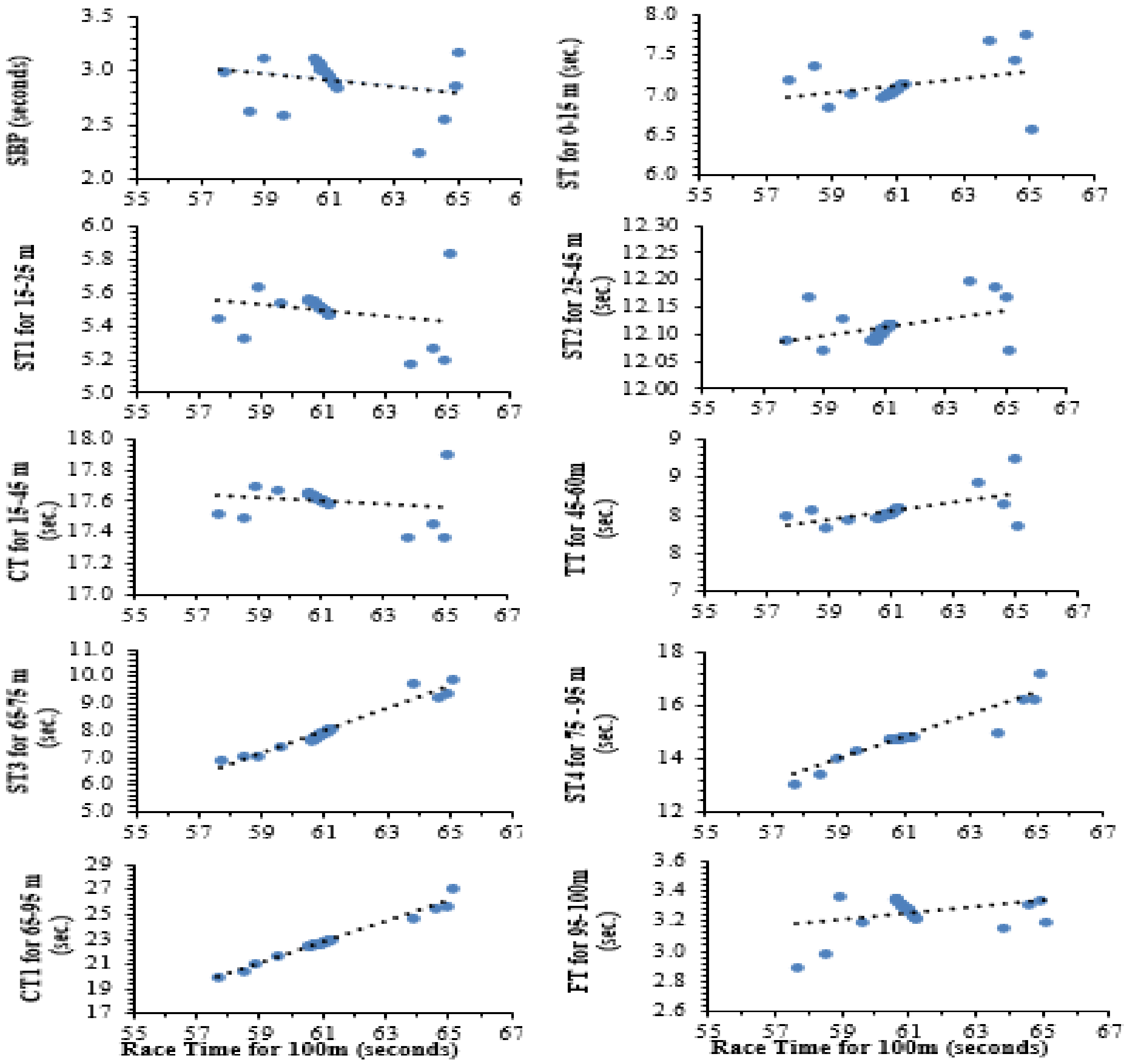

Figure 4: Relationship between race components (RCs) and Race Time of 100 m Freestyle.

It is evident that the prediction models for SBP, ST, ST_1, ST_2, CT_1, TT, and FT were very poorly fit because the value of R^2 was very small. Models for SBP, ST, ST_1, ST_2, CT_1, TT, and FT were insignificant ($p > 0.05$). So, the prediction of time for SBP, ST, ST_1, ST_2, CT_1, TT, and FT of Pakistani swimmers on the basis of RT of freestyle 100 m would not be statistically appropriate.

The prediction models for ST_3, ST_4, and CT_2 (Table 2) were highly significant ($p<0.001$). These models were the best fit because the values of R^2 were 0.95, 0.89, and 0.97. This indicated that the 95%, 89% and 97% variation in variable ST_3, ST_4 and CT_2 respectively can be concluded on the basis of RT of freestyle 100 m. It was noted that the values of S.E. for ST_3, ST_4, and CT_2 were very low which indicated that prediction model's values were adequate.

Table 2: Simple Linear Regression Estimates for prediction of 100 m Freestyle

Prediction Models	R^2	S.E.	F	P-Values
SBP = 3.72 - 0.02 RT	0.03	0.34	0.15	0.71
ST = 5.21 + 0.03 RT	0.07	0.42	0.44	0.53
ST_1 = 6.17 - 0.01 RT	0.03	0.25	0.17	0.69
ST_2 = 11.76 + 0.01 RT	0.14	0.05	0.95	0.37

CT = 17.91 - 0.01 RT	0.01	0.20	0.06	0.80
TT = 5.05 + 0.05 RT	0.28	0.29	2.28	0.18
ST_3 = -16.48 + 0.40 RT	0.95	0.33	113.39	0.000***
ST_4 = -11.76 + 0.43 RT	0.89	0.53	48.90	0.000***
CT_1 = -28.24 + 0.84 RT	0.97	0.47	229.13	0.000***
FT = 1.39 + 0.03 RT	0.32	0.15	2.80	0.15

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

IV. DISCUSSION

The results revealed that Pakistani swimmers' performance was not satisfactory in all race components (RCs). It has been reported that international swimmers performs better in starts, turns and finishes in comparison to national swimmers due to higher average velocity (Kjendlie et al., 2006; Veiga, Mallo, et al., 2014). There was a huge difference of 12.49 seconds in the Race Times (sec) of Pakistani (61.61) and International swimmers (49.12). Mean time of 100m men freestyle race at Japanese national swimming championship from 2012 to 2014 was 50.80±0.88 (Suito et al., 2015). The difference between means times of Japanese and international swimmers were 1.68 seconds which is marginal as compared to Pakistani swimmers. This huge difference of 12.49 seconds between Pakistani and International swimmers ultimately reflected performance level of Pakistani swimmers.

Starting phase have an impact of 15% in the total race time of 100 m events which is highly critical (B. Mason & Cossor, 2001; Skyriene, 2016). In present study, the Pakistani Swimmers spent 12% during starting phase which indicated that remaining race components took relatively longer time to complete. Swimming velocity of athletes were greatly affected by Starting movements and efficient turning of elite swimmers (Veiga & Roig, 2017). There was significant difference (1.54 s) in starting time (ST) as Pakistani swimmers lacked appropriate techniques in start. Starting and turning velocities should be maximized above 2.0 ms^{-1} in the freestyle events (Veiga, Mallo, et al., 2014) whereas the starting and turning velocities were 2.1 ms^{-1} and 1.8 ms^{-1} respectively indicating significant room for improvement in turning. The difference in race time can be significantly abridged by improvement in turning and avoiding dip in stroking speed after that (Veiga, Cala, et al., 2014).

International swimmers performed far better than the Pakistani swimmers in Surface Break Point (SBP) as their mean SBP was 38.85% better than local swimmers. Local athletes were not able to glide long underwater in start. This better SBP helps to achieve higher starting velocity (Skyriene, 2016; Vantorre et al., 2010). During the glide phase after the start, high level swimmers presented a longer gliding distance and higher start dive velocity than regional swimmers (Cossor & Mason, 2001; Durović et al., 2012; Elipot et al., 2009; Veiga, Cala, et al., 2014). Faster starting velocities and higher SBP can be achieved through improvements in the underwater swimming (Bruce Mason, 1999; Veiga & Roig, 2016). Therefore, local swimmers need to improve their starting skills to come at par with the international athletes.

There was a huge difference of 23.80% in starting velocities of Pakistan and international swimmers in starting phase. At the beginning of the race, start velocity can be clearly determined by the skill of the swimmer, in the absence of any previous fatigue (Tourny-Chollet et al., 2002). Local swimmers were slow off the blocks and could not attain higher velocity during starting phase whereas previous studies have reported that elite swimmers take advantage of starting phase by achieving high starting velocity (Smith, 2014; Vantorre et al., 2010).

Pakistani swimmers could not put up a satisfactory performance in the stroking phase. They could not able to uphold stroking velocities from 15 to 45 m (CT_1) and 65 to 95 m (CT_2). Elite swimmers have the capability to uphold the speed in stroking phase (Toussaint et al., 2006) and turning velocities (Chatard et al., 2001; Thompson et al., 2000; Veiga, Cala, Frutos, et al., 2013). Results of the current study were in line with previous research showing that the international swimmers sustained stroking and turning times whereas the Pakistani swimmers showed variable pacing profile during stroking, especially in the second lap in which they took 32.74% more time than the first lap whereas international swimmers were only 8.39% slower during the second lap. Lack of strength can be reason of the decrease in stroking velocity after turning (Veiga, Cala, et al., 2014). Moreover, the Pakistani swimmers could not able to keep apnea conditions as compared to their international counterparts.

Further data analysis of local swimmers revealed that there was a visible increase (2.54 sec) in the standard deviation for the stroking time of last lap as compared to first lap whereas this difference was negligible (0.09 sec) for international swimmers. This increase in the standard deviation of mid-pool swimming speed coincided with a marked increase in stroke variation (Thompson et al., 2000; Vorontsov, 2003). Results of this study showed huge variation in performance of Local swimmers.

Average velocities of Pakistani swimmers for both starting and turning phases were faster than the free-swimming speed. Same results have been reported in previous research work (Veiga, Mallo, et al., 2014). In the present study, average speed of stroking was found to be lower than starting speed (30.79%) and turning speed (22%). This increase in speed during starting and turning is primarily due to the fact that athletes were able to get a push from the wall (Takeda & Nomura, 2006) and the resistance forces are lower in underwater (Marinho et al., 2009). In the present study, a comparatively huge difference (30.79%) in the starting and stroking speeds highlighted the ineffective stroking of the local swimmers.

The turning movements are depend on skills of the swimmer (Shimadzu et al., 2008; Veiga, Cala, et al., 2014). In the present study, Local athletes took higher turning time (8.14 s) in comparison to their international counterparts (7.03s). Pakistani swimmers took significantly higher (15.79%) time in turning as compared to their international counterparts. A longer underwater glide and covering longer distance can enhance the performance in turning (Blanksby et al., 1996; B. Mason & Cossor, 2001; Puel et al., 2012; Veiga, Cala, et al., 2014). This has been highlighted in other studies that elite swimmers gain better underwater velocity by gaining greater force from the wall through push (Araujo et al., 2010; Blanksby et al., 1996) and by demonstrating a greater underwater kicking efficiency (Veiga, Cala, Frutos, et al., 2013; Veiga, Cala, et al., 2014; Zamparo et al., 2012). Therefore, swimmers must organize their turning movements by determining the optimal underwater distance in order to maximize underwater velocity. Surface breakpoint after turning was not in the scope of this study which can be studied in future research work to analyze the gliding phase of local swimmers after the turn.

Both International and Pakistani swimmers upheld stroking velocities at the end of racing events in the finishing phase. However, the velocities of Pakistani swimmers during finishing phase were on an average 29% lower than their international counterparts. This is possibly a result of better technical ability or faster approach speeds resulting in faster finishing speeds (Thompson et al., 2000). However, in the finishing phase of 100 m race events, fatigue and apnea conditions also play a crucial role in the performance of swimmers.

Thompson and Haljand (1997) calculated that male British Championship finalists, in comparison with European Championship finalists, took 0.62 s longer in the 100 m event, to complete the start, turns and last 5 m of the race. In the present study, local swimmers took 3.30 seconds longer than their international counterparts to complete these race components. Local swimmers have to work on their technique through scientific coaching and specific training.

The results revealed that only for ST_3, ST_4 and CT_1, prediction models were significant ($p<0.001$). In a similar study (R. Arellano et al., 1996), mathematical models for race components were developed, these were significant ($p<0.01$) for all race components except FT. Mathematical model for race components were also formulated and validated in a similar study by Suito et al. 2015.

V. Conclusion

Lack of scientific knowledge about the sport in coaches and athletes leading to ineffective coaching and training; non-availability of professional training facilities at grassroots level are primary reasons behind the difference in performance The results presented here provide an evaluation summary of performance of Pakistani swimmers in contrast to their international counterparts and also equip local coaches that where the weakness exit as wells providing them mathematical model on the basis of Pakistani swimmers' performance. Pakistani swimmers have to work on all race components especially on the starts, turn and finish as well as on the strength and training as their performance gradually decrease in stroking phase mathematical models provided by this study can be used by coaches for young athletes for focused training on identified weak areas in race.

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