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Original Article

Optimal race analysis parameters of freestyle swimming events: A case study

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Abstract

Introduction: During the swim meet, race analysis is a common practice to provide insight into each event. This case study explores the variables of swimming performance using the video analysis method.

Purpose: To determine the best indicator from a set of swim variables (digitised from video) for competitive swim races by one Malaysian freestyle swimmer in preparation for the Tokyo Olympic Games 2020.

Methods: Race video footage was analysed retrospectively to determine the key parameter for each event distance. The following variables were calculated: start time, end time (ET), turn time (TT), stroke count, stroke length, stroke rate, average velocity (AV) and stroke index. Differences were subsequently assessed among the parameters within the same event style.

Results: The results from the correlation test between the eight digitised variables and final time (FT) showed that for both 200 and 400 m events the variables AV (respectively, $r = -0.96$ and $r = -0.94$) and TT (respectively, $r = 0.89$ and $r = 0.83$) were significantly correlated. In addition, for the 200 m events, the ET also significantly correlated ($r = -0.94$) with FT.

Conclusion: This swimmer and over this period of Olympic qualifiers competitions, AV and TT were the best indicators for swim performance. Regarding the 200 m events, the end (sprint) time may also be an indicator.

Key Words: Freestyle, race analysis, swimming stroke, swimming, turn time, video digitisation

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INTRODUCTION

Over the past decades, elite swimming has become more competitive than ever, and Olympics qualifying times have become faster (Mujika et al., 2019). Concurrently, performance analysis of swimming has become increasingly sophisticated. A quantitative analysis of a competitive swim race may indicate potential improvements in technical and tactical aspects to improve swim time (Mason and Fowlie, 1997). Performance analysis of swimming could utilise several different technologies from a simple stopwatch and video digitisation (converting to information) to sophisticated inertial sensors (Mooney et al., 2015a). In theory, a range of variables can be collected from competitive swim races, providing various information. Depending on the technology and variable, varying turn-around times exist before available feedback to investigators, sports scientists, coaches, or swimmers. Furthermore, modern technology, such as inertial sensors, may provide near-real-time feedback (Mooney, et al., 2015b). Such technology is more resource-intensive (*i.e.* purchase cost, workforce and time-consuming) than video cameras. Hence, affordable video cameras are a common practice for a competitive swim race analysis (Gonjo and Olstad, 2020). However, which variables from video digitisation will give the most effective feedback for

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a competitive swim race while optimising the turn-a-round time has not yet been explored.

Video digitisation is widely applied to analyse a competitive swim race. Multiple investigators have studied a range of variables digitised from video, for example, stroke rate, stroke length, stroke cycle, kicking rate and velocity. In addition, the non-free swimming phase; includes start time, turn time, underwater distance and entry angles of the shoulder, elbow, and wrist (Arellano et al., 1994; Mason and Fowlie, 1997; Mooney et al., 2015b). Variables from competitive swim race races are considered the most important variables affecting skill gain and future race tactics (Hughes and Franks, 2007). Ultimately, swimming performance is determined by the official swim time to complete the event distance. Of interest is whether certain variables (digitised from video) related to specific aspects of swimming are more associated with the final swim time than other variables. A study by Mooney et al. (2015b) identified the turn to contribute significantly to the overall swim performance compared to other swim variables. The effect of other variables is still unclear. Stroke length, the distance covered per stroke, was the single best indicator for the middle-distance performance in one study (Costil et al., 1985) but was not significantly correlated with the final swim time in another study, similar to other stroke variables like stroke rate and stroke index (Arellano et al., 2002). Despite the potential number of variables digitised from video, it is unclear if there is a consensus, *i.e.* among coaches, regarding a best practice. The various studies applied to the lack of consensus explained by the different methods (*i.e.* camera setup, type of stroke, event, purpose, variables of interest and level of performance). Subject to the purpose of the analysis, the more variables to digitise from video, the longer the turn-a-round time will be. The question then arises about which variables are the best indicators of competitive swim performance to provide timely feedback.

In this case study, a retrospective analysis was performed to determine the best indicator from a set of swim variables (digitised from video) for competitive swim races by one Malaysian freestyle swimmer in preparation for the Tokyo Olympic Games 2020. In addition, we investigate whether the best indicators could differ for the same swimmer if different distances have swum. It is common practice for an elite swimmer to train and compete in multiple distances. The hypotheses for this study are that (i) turning time and (ii) stroke length are variables significantly associated with the final swim time for both 200 and 400 m distances using freestyle stroke.

METHODS

Competitive swim races by one Malaysian male swimmer (age: 22 years in 2017; weight: 70 kg; height: 1.81 m) were analysed retrospectively to determine which swim variables digitised from the video are best associated with final swim time. Video of the fastest swim race during the competition was digitalised to attain a range of swim variables for analysis. Competitions (n = 6) were held from 2017 to 2019, two each year, were organised locally (National Open) and officially recognised by International Swimming Federation (FINA). From each competition, two events were analysed, the 200 and 400 m freestyle. Video of the fastest swim race only was included for analysis, regardless of preliminary or final stage races. Swim races were recorded using a Sony 4K FDR-AX100E video camera at 50 Hz from an elevated position with a static view of the entire length of the pool. The mentioned frame rate was considered sufficient for this study; since the video footage was only for above-water stroke action, and the motion of the swimmers is comparatively slow (Arellano et al., 1994). To track and time the approximate location of the swimmer and the pool, his head position relative to the colour floaters (at fixed distances) of the lane dividers was estimated on the video images. The floaters on the lane dividers are separated at regular intervals and have an alternative colour at 5 m, 10 m, 15 m and 25 m from either side of a 50 m lane (Arellano et al., 1994). For every lane of 50 m swum, the "'middle"' 35 m was labelled as the free-swimming phase, not counting 5 m before or 10 m after a turn. An exception was there for the first 50 m when the free-swimming phase is only 30 m long because the start was considered to cover the first 15 m (5 m more than the 10 m after a turn). The video footage was analysed using computer video software for the sport called Silicon Coach (Ver.7, The Tarn Group, Dunedin, New Zealand), which has the tools to measure swim variables in every frame (0.02 s) of the video and export variable data to third-party software.

The swim variables chosen to digitise in this study were the most common variables analysed in previous literature using video digitisation. Nine variables were collected; one variable, Final Time (FT), was the official swim time measured by the event organiser. The fastest race of each event in every competition, with eight variables, was digitised from the video. The eight digitised variables are start time (ST), end time (ET), turn time (TT), stroke count (SC), stroke length (SL), stroke rate (SR), average velocity (AV) and stroke index (SI). Start time is the time from the start to the first 15 m. End-time is calculated during the last 5 m of the event. Turn time is clocked from 5 m before the wall to 10 m after push-off from the wall. Stroke count is defined as the total number of completed strokes that a swimmer executed. Stroke length is the distance a swimmer's head (as the point to track) travels during a complete arm stroke, for example, from the left-hand entry to the next left-hand entry. Stroke rate is the average number of strokes per minute and was calculated over the stroke times of every single stroke. Average velocity is the number of meters covered per second and was calculated over the SL divided by the stroke time of every single stroke. The stroke index, an indicator of stroke efficiency, is the product of AV and SL (Arellano et al., 2002). The latter five variables were calculated based on every stroke during all the free-swimming phases of the fastest race, of 200 and 400 m event, during the competition.

Data of all variables from each competition event were used in the analysis. In total, 12 competitive races were digitised, six times 200 m races and six times 400 m races. The method to determine the best indicator of competitive swim performance was to

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calculate the average of 8 digitised variables of each competitive swim race for each event and was tested for significant correlation with FT. All statistical calculations were performed with the Statistical Package for the Social Sciences version 21 (IBM Inc., Chicago, Ill, USA) for Windows.

RESULTS

The FT for each of the fastest competitive swim races between 2017 and 2019 for 200 and 400 m ranged from, respectively, 01:47.48–01:50.11 (minutes:seconds) and 03:50.26–03:57.89 (minutes:seconds). The average value (and standard deviation) of the eight variables digitised from the video is shown in Table 1. The correlation coefficients between the eight variables of both 200 and 400 m events and the FT are shown in Table 2. The results from the correlation test between the 8 digitised variables and FT show that for both 200 and 400 m events the variables AV (respectively, $r = -0.96$ and $r = -0.94$) and TT (respectively, $r = 0.89$ and $r = 0.83$) were significantly correlated. In addition, for the 200 m events, the ET also significantly correlated ($r = -0.94$) with FT.

DISCUSSION

This study aimed to determine the best indicators of competitive swim performance for one Malaysian freestyle swimmer analysed from competitive swim race performances in the 3 years before the Tokyo Olympic Games 2020. Results show that AV and TT significantly correlate with FT for the 200 and 400 m freestyle event, and additionally that ET significantly correlates with FT for the 200 m event. AV is negatively correlated with FT, so if AV increases, the FT decreases. TT is positively correlated with FT, so if TT increases, the FT also increases. For the 200 m event, TT is positively correlated with FT, so if TT increases, the FT also increases. Two variables are leading indicators for the swim performance of this athlete for the 200 and 400 m freestyle event, with a difference that ET is essential for the shorter 200 m event. The mentioned variables implicate that AV and TT, and in the event of 200 m also ET, should be the main/primary variables to measure when evaluating swim performance. Compared to digitising eight variables, measuring 2–3 variables will ensure the quickest feedback turn-a-round while providing practical information.

The significant correlations found in this study are logical in that the AV calculated over the free-swimming phases that cover most of the event distance affects the FT. Following the first hypothesis, the TT involves a change in direction (effectively stopping to zero velocity in between) and is performed 3 or 7 times depending on the event distance. It is a good indicator of competitive swim performance because the faster this turn can be accomplished, the less total time is lost. Unexpectedly, contrary to the second hypothesis, the variables related to the stroke (SC, SL, SR and SI), especially stroke length, were not significantly correlated with FT. Notably, all the stroke variables are interrelated either based on SL, stroke time, or both. The statement suggests that FT is relatively unaffected by the stroke technique and that AV may be achieved irrespective of the value of these stroke variables. This is against Costil et al. (1985) and in line with findings by Arellano et al. (2002). The variable ET is also an indicator for 200 m performance FT because the FT of such a "'short"' event (*i.e*. long sprint) will likely benefit from the last burst of effort to the finish.

This study determined the best indicators of competitive swim performance by one highly trained male swimmer from Malaysia in the run-up to the Tokyo Olympic Games 2020. Retrospectively, the best indicators were determined from a set of swim variables that were digitised from actual competition videos between the years 2017 and 2019. Competition footage was preferred over training footage to assess actual swim performance demonstrated at an official stage. Irrespective results from this analysis of competitive swim races may be beneficial for comparison with swim performances during training and not merely beneficial for comparison to competitive swim races. After all, it may be beneficial to benchmark performance during training with meaningful values from previous competitions. In 2019, the swimmer qualified for the Tokyo Olympic Games 2020, achieving the Selection Time ('B' Time) in 200 and 400 m. Following this study, the best indicators for his swim performance were determined and will facilitate efficient and practical feedback to investigators, sports scientists, coaches, or swimmers.

Some limitations in this study have to be considered. This case study included the competitive race performances of one single swimmer and inherently has individual bias. The indicators identified in the results may not necessarily be transferrable to other swimmers. For the same reason, the results may also not be transferrable to the performances of different strokes. Future research should investigate digitised variables (from video) from multiple swimmers and different strokes to determine their importance. The variables investigated in this study were limited to the most common variables used in referenced literature. Less common variables, for example, kicking rate should be included in future studies but may rely on different measurement technology because it may be unreliable to digitise this from the above water video. The results from this study may also not be transferrable to other race distances because these were not included. However, the results in this study of the best indicators for the 200 m event

Table 1: Descriptive data for the experimental variables between 200 m and 400 m freestyle

	ST (s)	ET (s)	TT (s)	SC (*n*)	SL (m)	SR (strokes/min)	AV (m/s)	SI (m²/s)
200 m	5.12±0.38	2.85±0.14	7.64±0.11	63.5±2.0	2.45±0.06	43.28±1.53	1.76±0.02	4.32±0.08
400 m	5.10±0.66	2.88±0.17	8.10±0.15	120.5±3.0	2.63±0.05	37.40±1.14	1.63±0.02	4.29±0.08

Data are expressed as mean±SD. SD: Standard deviation, ST: Start time, ET: End time, TT: Turn time, SC: Stroke count, SL: Stroke length, SR: Stroke rate, AV: Average velocity, SI: Stroke index

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Table 2: Correlation coefficients for 200 m and 400 m freestyle

	FT	
	200 m	**400 m**
ST	0.76	0.65
ET	0.94*	−0.40
TT	0.89*	0.83*
SC	−0.42	−0.16
SL	0.68	0.55
SR	−0.74	−0.80
AV	−0.96*	−0.94*
SI	0.42	−0.15

*Correlation is significant at the 0.05 level (two-tailed). ST: Start time, ET: End time, TT: Turn time, SC: Stroke count, SL: Stroke length, SR: Stroke rate, AV: Average velocity, SI: Stroke index, FT: Final time

may be more applicable to sprint-type races. In contrast, the results for the 400 m event may be more applicable to medium-long distance races. Besides the individual bias in this study, the swimmer from Malaysia may also not be representable to swimmers from other continents (*e.g.* European, North-American swimmers). Again, a future study should investigate differences in indicators of competitive swim races across continents. No inter- and intra-reliability study were performed beforehand. The data collection and analysis mainly were part of a service provided by the Biomechanics department member of the National Sports Institute of Malaysia, who consistently digitised variables from the video since 2015. Last but not least, the results of this study do not implicate those other variables that are not worthy of attention by sports scientists, coaches and swimmers to seek improvements (this may also depend on the newly gained insight of particular aspects of swim improvements). It could be that the best indicators differ per race, but it was beyond the scope of this study to determine such in-depth relationships.

CONCLUSION

The study aimed to determine the best indicators of competitive swim races by one Malaysian freestyle swimmer from 2017 onward in preparation for the Tokyo Olympic Games 2020. Potential indicators were tested from a set of swim-related variables digitised from video. In conclusion, for this single swimmer and over this competition time, the best indicators for swim performance were average velocity and turn time. Regarding the 200 m events, the end (sprint) time may also be considered an indicator. Caution is advised when attempting to transfer the relevance of the resulting indicators to different swimmers, strokes, or distances. Nevertheless, a similar race analysis method (video digitisation) may be adapted by coaches and swimmers with different swimming styles, including races outside competitions, to investigate detailed kinematic and physiological factors in swimming races.

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Conflicts of interest

There are no conflicts of interest.

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