# A COMPARISON BETWEEN SINGLE AND MULTI- CAMERA SWIMMING RACE ANALYSIS SYSTEMS

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This study compared the reliability of single and multi-camera race analysis systems. Thirteen swimmers were analysed during 25 different swims using two methods of data collection. The parameters selected for further investigation were start time, average swim velocity, average stroke rate, average stroke length and turn time. Mixed modelling was used to compare the mean differences and amount of random error of each system in between swims. Some differences between the means of each parameter exist, however the only meaningful difference was 1$^{st}$ turn time (0.21 s difference). There were also errors associated with both systems particularly with turn times and average velocity. This study reveals that a single camera analysis system is just as accurate as a multi-camera system.

**KEY WORDS:** parameter, reliability, mixed modelling.

**INTRODUCTION:** Race analysis is the provision and collection of data concerning a swimmer's race. In order to perform a race analysis, many systems have been developed which require video footage to be recorded from one or more video cameras operating from a central control panel or as separate video recordings (Smith, Norris, & Hogg, 2002). There are a number of different race analysis systems and methods that have been used over the years by many of the major swimming nations (Mason & Formosa, 2011). The most common types of race analysis systems are either a single camera system involving one camera mounted in the centre of the pool or a multi-camera system involving multiple cameras mounted at specifically set distances along the length of the pool. Currently, single camera systems are more common as they are largely more convenient to travel with; however there are no studies which have compared the two types of systems. The purpose of this reliability study is to compare the two types of race analysis systems and determine which system is more accurate.

**METHODS:** Full race analysis was performed for 25 separate swims. The 25 swims were swum by 13 different elite swimmers; 9 male and 4 female with a mean age of 21 ±3 y. Five swims were backstroke, 15 were freestyle and 5 were breaststroke. Thirteen of the trials were 100 m swims, 9 were 150 m swims and 3 were 200 m swims. The stroke and distances swum by each swimmer was determined prior to testing by their coach. All were performed as maximal time trials from lanes 4-6 leading into the 2011 Australian Championships.

Two different race analysis systems were used during each swim. The first system was a single camera system and all races were filmed using a Sony camcorder video camera (HDRFX1000), which recorded at 25 hz and captured using proprietary race analysis software issued by Swimming Australia Limited (SAL) called GreenEye Swim Analysis. The camera for this system was mounted on a raised platform using a tripod. The platform was positioned at the 25 m mark of a 50 m pool approximately 3.5 m high and 3 m perpendicular to the pool's edge (Figure 1). The second system used was a multi-camera system (Platypus) developed by the AIS Aquatic Testing, Training and Research Unit (ATTRU). This system uses three stationary cameras 3 m perpendicular to the pool's edge and recorded at 100 hz and one panning camera recorded at 50 hz, to locate where the swimmer is in the pool. Manual triggers are then used to gather data regarding swimming races in real time before a race report is generated for the coaches and swimmers. The setup for this system is shown in Figure 1. Prior to each testing occasion both systems were individually calibrated.

Both systems also utilised the same electronic timing system which was the Omega Ares 21 Timing System (3330.900, Corgémont, Switzerland).

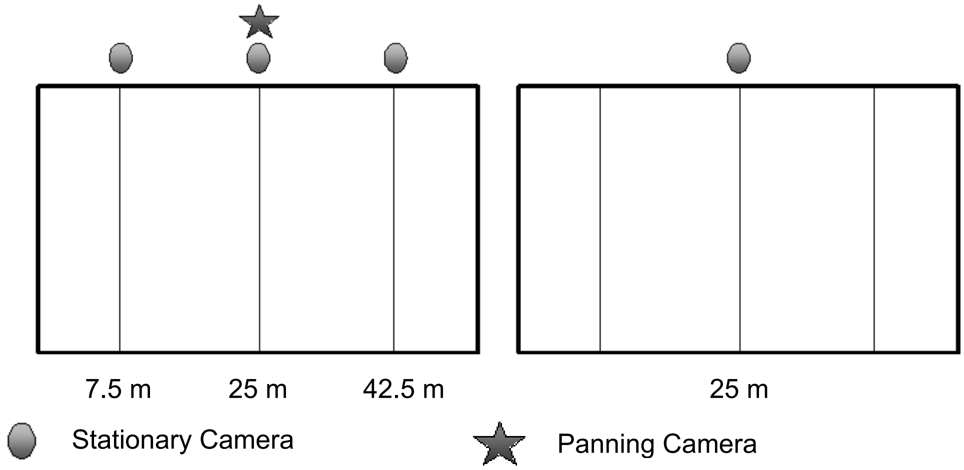


**Figure 2: Platypus pool set up (Left) and GreenEye pool set up (right).**

**Table 1: Parameters measured with each system and definition.**

| Parameter | Definition |
|---|---|
| Swim time | The total time taken to swim the entire distance of the race. This is the overall race time which was entered into the software using the time obtained from the electronic timing system. |
| Splits for 25m and 50 m | The time taken to swim each 25m and 50m distance of the race. To calculate this, the analyser identified when the centre of the swimmer's head crossed the centre of the pool to obtain the 25m splits for each race. The 50m splits were obtained using the electronic timing system. |
| Start time | The time taken for the centre of the swimmer's head to reach the 15m mark after the start signal. |
| Turn time (in and out turn times) | Time from the head at 5 m away from the wall on approach to when the head reaches 10 m away from the wall on departure from the wall. |
| Swim velocity | The velocity at which the swimmer is travelling. Calculated using the formula distance (m) over time (s). The velocity was calculated only for the free swimming segments of the race. These segments do not include the distances used to calculate skill times. |
| Stroke rate, stroke count | The number of stroke cycles that would occur in a minute (stroke rate). |
| Stroke length | This is the distance the swimmer travels through the water during one complete stroke cycle (i.e. right hand entry to right hand entry). This was calculated by multiplying the stroke rate (converted to seconds per stroke) by the swim velocity. |

The parameters that were chosen for further investigation were start time (s), average velocity ($ms^{-1}$), average stroke rate (str/min), average stroke length (m), turn time (s), in turn time (s) and out turn time (s). The way each of these parameters was measured is shown in Table 1.

SPSS was used to perform mixed modelling in order to compare the difference in means for each parameter and the amount of variance (random error) which occurred during data collection for each system in between systems. Velocity, stroke rate and stroke length were log transformed before analysis to account for stroke and distance differences.

Two different models were used; the first model identified the difference in the mean for each parameter while the second model measured the amount of random variation for each parameter between trials. The smallest worthwhile change was determined for each parameter based on previous literature (Pyne, Trewin, & Hopkins, 2004) before magnitude based inferences were made using methods based on Batterham and Hopkins (2006). The smallest worthwhile change was not determined for stroke rate and stroke length as there was no previous literature.

**RESULTS:** Table 2 shows the fixed effects model and compares the differences in the mean for each race-analysis system. Table 3 shows the random effects from mixed modelling and shows a comparison of the amount of random error between each swim for each system.

**Table 2: A comparison of mean differences between GreenEye and Platypus for each parameter.**

| Parameter | GreenEye | Platypus | Difference in Mean | Confidence Limits | Smallest Worthwhile Change | Magnitude |
|---|---|---|---|---|---|---|
| Start Time | 6.79 s | 6.73 s | 0.06 s | ±0.05 s | 0.13 s | Very likely trivial |
| Avg. Velocity | 1.62 $ms^{-1}$ | 1.65 $ms^{-1}$ | -0.47 % | ±1.01 % | 0.30 % | Unclear |
| Avg. Stroke Rate | 45.1 $min^{-1}$ | 44.8 $min^{-1}$ | 0.65 % | ±0.65 % | * | * |
| Avg. Stroke Length | 2.19 m | 2.17 m | 0.10 % | ± 0.40 % | * | * |
| 1st Turn Time | 8.45 s | 8.24 s | 0.21 s | ±0.06 s | 0.13 s | Very Likely Positive |
| 1st In-Turn Time | 3.19 s | 3.20 s | -0.01 s | ±0.30 s | 0.13 s | Most Likely Trivial |
| 1st Out- Turn Time | 5.22 s | 5.12 s | 0.10 s | ±0.09 s | 0.13 s | Possibly Positive |

**Table 3: A comparison of error of measurement between each swim for GreenEye and Platypus for each parameter**

| Parameter | GreenEye Error | Platypus Error | Difference in Error | Confidence Limit | Smallest Worthwhile Change | Magnitude |
|---|---|---|---|---|---|---|
| Start time | 0.12 s | 0.12 s | 0.03 s | ±0.03 s | 0.07 s | Most Likely Trivial |
| Average Velocity | 2.80 % | 1.80 % | 1.00 % | ±1.13 % | 0.15 % | Likely More |
| Average Stroke Rate | 4.40 % | 4.40 % | 0.00 % | ±0.30 % | * | * |
| Average Stroke Length | 2.41 % | 2.45 % | -0.04 % | ±0.06 % | * | * |
| 1st Turn Time | 0.17 s | 0.23 s | -0.06 s | ±0.05 s | 0.07 s | Possibly Trivial |
| 1st In-Turn Time | 0.28 s | 0.59 s | -0.31 s | ±0.09 s | 0.07 s | Most Likely Less |
| 1st Out- Turn Time | 0.26 s | 0.08 s | 0.18 s | ±0.04 s | 0.07 s | Very Likely More |

**DISCUSSION:** This study used a novel study design and statistical methods to compare two race analysis systems. Anecdotally, it was assumed among many sport scientists that multi-camera approaches to race analysis would provide more accurate data collection when compared to a single camera approach. This is because a multi-camera approach is assumed to eliminate possible parallax error associated with using a single camera. Furthermore, the increased recording rate of the multi-camera system would be assumed to lead to more accurate analysis. The data analysis in this study does not reflex this. When comparing the mean differences in measurement between each of the systems it was found that there were small trivial differences in all parameters except for average velocity (difference in mean; -0.47, magnitude; possibly negative) and turn time (0.2; very likely positive). These results would suggest that there are no substantial measurement differences between each of the systems for the other parameters. The same measuring distances are used for both systems so the differences in measurement for velocity and turn time are due to either parallax error or individual tester error associated with each system.

When comparing individual parameter error for each system there was more inter-trial error associated with stroke rate and turn times (in and out). Even though there were large errors associated with these parameters, the amount of error was similar for both systems and seems to be indicative of race analysis. These differences include technical error but could also be caused by individual differences such as skill of tester. Again, the most substantial difference between each system were between velocity (-1.0%; likely more), in-turn time (-0.31 s; most likely less) and out-turn time (0.18 s; very likely more). Overall, the amount of random error between each system is dependent on the individual parameter and no system can be determined to be more accurate than the other based on the statistical analysis performed.

Given both systems were found to have a similar amount of variability it is difficult to determine which system is superior. A multi-camera system similar to that described above will allow for concurrent analysis during the swim which could potentially allow for faster analysis; however the setup and equipment required for the system is much more sophisticated which may make the system difficult to travel with. A single camera system is also the preferred system for most major swimming nations during international meets as they are easy to travel with and relatively simple to calibrate and setup. However, analysis cannot be done concurrently with many single camera systems and analysis can be lengthy.

**CONCLUSION:** Contrary to anecdotal opinions the results from this study show that a single camera system used by a skilled operator appears to be no less accurate than a multi camera system. Therefore, in the future major swimming nations should move to developing single camera systems, which allow for real time analysis.

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