WHAT CAN WE LEARN FROM COMPETITION ANALYSIS AT THE 1999 PAN PACIFIC SWIMMING CHAMPIONSHIPS?

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An analysis of the 1999 Pan Pacific Swimming Championship competition analysis data from Sydney indicated that the relationship between the quality of the swim performance and stroke length was not significant as is commonly assumed in swimming arenas, apart from a few events. The average free swimming speed was significantly correlated to race results for all events, but this was to be expected. The next most highly correlated variable with race performance was the turn time, which was significant in 92% of all events. Start and turn times along with free swimming speed were considered significant in all of the form strokes. This was similar to the freestyle events but these races also showed that the finish time was an important part of obtaining a good race result. The second half of the race was more strongly related to race performance than the first half of the distance races in all events except for the women's 400m Freestyle. In the individual medley events, turn performance was significantly related to race performance. It was found that the most significant individual stroke within the medley races was breaststroke followed by backstroke, butterfly and freestyle. The above information is considered accurate for elite level swimmers and can be used to develop a general competition model. It should be remembered that the information is based on the top eight or 16 swimmers in each event so may not be specific to a particular swimmer and that the final competition model should be suited to the individual.

KEY WORDS: Pan Pacific Championships, swimming, competition analysis, performance, elite.

INTRODUCTION: The Biomechanics department in the Australian Institute of Sport conducted the competition analysis at the 1999 Pan Pacific Swimming Championships in Sydney. Students from the University of Western Sydney, University of Technology – Sydney, the Australian Catholic University and Sydney University, assisted in this project. The analysis involved 34 students and 7 staff working shifts of 6 hours around the clock. Data was analysed for all swimmers who qualified for the semi-finals and finals in every individual event. The competition analysis provided information on start time (to 15m), turn times (7.5m into and out of the wall), and finish time (5m into the wall). The stroke length, stroke frequency and velocity for each 25m section of free swimming (i.e. no start, turn or finish interaction) were also calculated.

Each swimmer was given a printout with this information as well as a spreadsheet that compared the top 16 swimmers after the heats and all of the finalists after the finals. Three graphs were also produced to describe the race in a pictorial representation. The first graph indicated the velocity for each section of the race and was a comparison between the individual and the first three place getters/qualifiers, the second contained the same information without the start, turn and finish velocities included and the final graph plotted the interaction of stroke length, stroke frequency and velocity throughout the race for the swimmer. Following the end of the competition, a booklet containing the spreadsheets of the finalists in each event was compiled and provided to each of the competing nations before they departed from Sydney. Coaches could then determine weaknesses in their swimmer's performance and race strategies of their main competitors from the information in the race booklet. The competition result booklet could also be used into the future when rule changes or technique changes are made and the impact of these could be made on an athlete's race performance. The information could be used by an individual to determine how their race had changed over a period of time (from competition to competition) and how they compared to the other competitors at the same competition to identify if they needed to change their own race plans to remain competitive.

The information provided to the coaches and athletes assisted to prove their performance in

two ways. The first was at the competition where the coach could identify an area that the athlete was not performing adequately and try to focus on this for the finals. An example of this would be where an athlete was losing a great deal of time in the turns during the heats and wanted to focus on turns in the semi-finals or finals to improve performance. The second involved a more long-term strategy where the coach and athlete worked on identified weaknesses in a training environment, so that the problem became more automatic for the athlete in future competition. If the turns were highlighted as a problem, when compared with other swimmers in the competition analysis, the coach and athlete could work more on the turns during training so that the same deficiency would not occur in future competitions. Weaknesses could be determined both from the individual printout as well as the graphs and spreadsheets when used in comparison to the faster swimmers. The competition model may be changed once a weakness was identified and the coach would then need to work with the swimmer on this new model.
Statistical analyses could be conducted on the information provided by the competition analysis to determine elements of the race that were considered important in determining the final result. The coach and athlete could then work closely on the variables that affected the result. The information from the competition analysis could therefore be useful to the swimmer and coach in two ways. This research project attempted to identify important variables affecting performance from the competition analysis at the 1999 Pan Pacific Championships.

METHOD: A Pearson Product Moment Correlation statistical programme was used on the data from the competition analysis to determine any relationship between the race result (criterion variable) and other variables calculated in the competition analysis (independent variables). The race result was considered the most important variable in race performance, which is why it was used as the criterion measure. The top 16 swimmers were analysed for each of the shorter races (50m, 100m and 200m) while the fastest 8 swimmers were used for the analysis in the 400m, 800m and 1500m events. As these swimmers were considered to be some of the best in the world at the time of competition, the results from these analyses are considered to have direct relevant implications for elite swimmers.
The independent variables included the free swimming time, which is the time in a 25m section that does not include the start, turn or finish velocity. Other independent variables used were the start time, turn time, finish time, stroke length, stroke frequency and efficiency index. Stroke length and stroke frequency were counted as complete cycles so in freestyle and backstroke it was calculated as the time from right hand entry to the next right hand entry. The efficiency index is a product of the stroke length multiplied by velocity, as there is a general perception that stroke length is an important aspect of efficiency in swimming.
The purpose of the present study was to determine if any of the independent variables had a strong relationship with race performance for the finalists, as determined by the official results provided by Omega. The authors have noted that although there may be a strong correlation between two variables, this does not imply a cause and effect relationship. An example would be if there was a strong correlation between race performances and turn time; it does not imply that the turning ability of a swimmer was the predominant contributing factor in determining the race result. It may however suggest that a swimmer's ability to turn quickly may be a significant factor in determining the race result. This could be the case if all of the swimmers in the final had similar free swimming times and the major difference in race result was the turning times during the race. The statistical analysis displays common trends from all of the finalists, not just the overall winner, and some swimmers may have very different race plans. This needs to be remembered when coaches are working with the swimmers on their race plans so as to make sure that they look at all of the factors involved in the first placegetter winning the race and not just the highlighted correlation parameters.
The start time was the time from the gun until the swimmer's head passed through the 15m mark. The turn time was defined as the period from the swimmer's head passing the 7.5m mark on their way into the wall and then returned to this point after having completed the turn. Finish time was defined as the time that it took for the swimmer's head to pass under

the flags (5m from the wall) until the swimmer's hands touched the wall at the end of the race. The analysis was also divided into 25m sections in order to accurately determine the velocity through different phases of the race. Swimming velocity was measured for each 25m section of the race while the free swimming time was the time within a 25m section that did not include any start, turn or finish section. Stroke length (measured in metres) and stroke frequency (strokes per minute) were also calculated in each free swimming section of the race. Stroke length was defined as the distance that a swimmer travels for a complete stroke cycle (right hand entry to right hand entry in freestyle and backstroke). The number of stroke cycles that would occur in one minute if the present rating were continued was defined as the stroke frequency. The efficiency index within a section was the product of stroke length and the average swimming velocity and was measured in m*m/s. It is important to note that efficiency indices cannot be compared between strokes and should probably not be compared between swimmers. It does appear that the change in efficiency throughout a race can be particularly useful measure for the swimmer. The larger the index number, the more efficient was the swimmer.

RESULTS: The independent variables that related highly to performance in the various events are provided below:

Freestyle 50m & 100m

MALES. In the 50m, free swimming time (0.85) and start time (0.84) had a significant correlation with performance. Both of these results were at the 0.01 level of significance. This was not an unexpected observation. In the 100m, free swim time (0.95), start time (0.50), turn time (0.86), finish time (0.52) and index (-0.61) all correlated with performance. The start and finish times were significant at the 0.05 level while the other variables were significant at the 0.01 level. This translated to swimmers decreasing their free swim, start, turn and finish times as the performance improved as well as having an increase in efficiency.

Table 1 Significant Correlations between Race Result and Independent Variables in Freestyle Races

Distance	Gender	Free Swim	Start Time	Turn Time	Finish Time	Stroke Length	Stroke Freq	Eff Index
50m	Male	**(0.85)	**(0.84)		*(0.52)			
50m	Female	**(0.95)	**(0.84)		**(0.83)	*(-0.41)		**(-0.61)
100m	Male	**(0.95)	*(0.50)	**(0.86)	*(0.52)			**(-0.61)
100m	Female	**(0.96)	**(0.73)	*(0.62)	**(0.82)			*(-0.55)
200m	Male	**(0.94)	**(0.74)	**(0.91)				
200m	Female	**(0.94)		**(0.79)	**(0.79)			
400m	Male	**(0.93)	*(0.72)	**(0.96)	**(0.86)	**(-0.83)		**(-0.90)
400m	Female	**(0.81)	*(0.68)	**(0.83)				
800m	Female	**(0.99)		**(0.86)	*(0.79)		**(-0.83)	
1500m	Male	**(0.98)	**(0.87)	**(0.96)	*(0.76)	*(-0.72)		*(-0.79)

Note ** indicates 0.01 level of significance and * indicates 0.05 level of significance

FEMALES. In the 50m, free swimming time (0.95), start time (0.84), finish time (0.83) and efficiency index (-0.61) were significant at the 0.01 level and the stroke length (-0.41) was significant at the 0.05 level. As performance improved, the stroke length and efficiency increased while the free swimming, start and finish times decreased. In the 100m, the free swim speed (0.96), start time (0.73), turn time (0.62), finish time (0.82) and efficiency index (-0.55) all correlated significantly with the race result. These were all significant at the 0.01 level except for the turn time that was at the 0.05 level of significance.

Freestyle 200m & 400m

MALES. In the 200m, free swim time (0.94), start time (0.74) and turn time (0.91) were related to race result at the 0.01 level of significance. This showed a trend of faster free swim, start and turn times with a faster race result. In the 400m, free swim time (0.93), turn time (0.96), finish time (0.86), stroke length (-0.83) and efficiency index (-0.90) were related at the 0.01 level of significance. Analysis of the two halves of the race showed that the free swimming speed in the second 200m (-0.97) correlated more highly than the first 200m (-0.82) with performance in the longer event. A sample size of eight swimmers was used for this analysis.

FEMALES. In the 200m, free swim time (0.94), turn time (0.79) and finish time (0.79) were all significant at the 0.01 level. Again, as the race performance improved, the free swim, turn and finish times decreased. In the 400m, free swim time (0.81) and turn time (0.83) were related at the 0.01 level of significance while the start time (0.68) was related at the 0.05 level of significance. That is as performance improved the free swimming time, start time and the turn time all decreased. Free swimming speed in the first 200m (-0.92) correlated with the race performance in the longer event at the 0.01 level while no correlation was detected with the second 200m and the final result. A sample size of 8 was used for this analysis.

Table 2 Significant Correlations with Halves of the Race in Freestyle Races

Distance	Gender	First Half Swim Speed	Second Half Swim Speed
400m	Male	**(-0.82)	**(-0.97)
400m	Female	**(-0.92)	
800m	Female	**(-0.95)	**(-0.99)
1500m	Male	**(-0.93)	**(-0.98)

Freestyle 800m & 1500m

MALES. In the 1500m, free swimming time (0.98), start time (0.87), and turn time (0.96) were significant at the 0.01 level. The finish time (0.76), stroke length (-0.72) and efficiency index (-0.79) were related at the 0.05 level of significance. The free swim, start, turn and finish times all decreased as the performance improved. The stroke lengths increased and efficiency index increased for the faster swimmers in the race. Free swimming speed in the second 750m section (-0.98) correlated more highly than in first 750m (-0.93) with race result. Both of the correlations were significant at the 0.01 level of confidence. A sample size of only eight swimmers was used in the analysis.

FEMALES. In the 800m, free swimming time (0.99), turn time (0.86) and stroke frequency (-0.83) were significant at the 0.01 level while the finish time (0.79) was significant at the 0.05 level. Free swimming speed in the second 400m (-0.99) correlated more highly at the 0.01 level of significance than the first 400m (-0.95). A sample size of only eight swimmers was used in the analysis.

Table 3 Significant Correlations with Independent Variables in Butterfly Races

Distance	Gender	Free Swim	Start Time	Turn Time	Finish Time	Stroke Length	Stroke Freq	Eff Index
100m	Male	**(0.92)	*(0.53)	**(0.78)				**(-0.65)
100m	Female	**(0.80)	**(0.77)	**(0.87)		**(-0.70)		**(-0.78)
200m	Male	**(0.95)	**(0.65)	**(0.88)	**(0.85)			
200m	Female	**(0.96)		**(0.85)				

Butterfly

MALES. In the 100m, free swimming time (0.92), turn time (0.78) and efficiency index (-0.65) were significant at the 0.01 level and start time (0.53) was significant at the 0.05 level of significance. That is, as the free swimming time, start time and turn times decreased, there was a trend for better performances. Simultaneously, there was a tendency for the efficiency index to improve with better race results. In the 200m Butterfly, free swim time (0.95), start time (0.65), turn time (0.88) and finish time (0.85) were significant at the 0.01 level of significance. Performance tended to improve as the free swim, start, turn and finish times decreased.

FEMALES. In the 100m Butterfly, free swimming time (0.80), start time (0.77), turn time (0.87) and efficiency index (-0.78) were related at the 0.01 level of significance. Performance improved as the efficiency index increased and the free swimming time, start time and turn time decreased. In the 200m, free swimming time (0.96) and turn time (0.85) were significant at the 0.01 level of confidence. In other words, the better placed swimmers had faster free swimming times and turn times than the lower placed swimmers.

Table 4 Significant Correlations with Independent Variables in Backstroke Races

Distance	Gender	Free Swim	Start Time	Turn Time	Finish Time	Stroke Length	Stroke Freq	Eff Index
100m	Male	**(0.75)	**(0.68)	**(0.89)				
100m	Female	**(0.74)	*(0.59)	**(0.82)	**(0.62)			
200m	Male	**(0.86)	**(0.61)	**(0.80)				
200m	Female	**(0.88)	*(0.55)	**(0.74)	*(0.50)			

Backstroke

MALES. In the 100m, free swim time (0.75), start time (0.68) and turn time (0.89) were significant at the 0.01 level of significance. In the 200m, free swimming time (0.86), start time (0.61) and turn time (0.80) were significant at the 0.01 level of confidence. As the race performance improved the free swim, start and turn times decreased for both distances.

FEMALES. In the 100m, free swim time (0.74), turn time (0.82) and finish time (0.62) were related at the 0.01 level of significance while the start time was significant at the 0.05 level (0.59). In the 200m, free swim time (0.88) and turn time (0.74) were significant at the 0.01 level and start time (0.55) and finish time (0.50) were significant at the 0.05 level. A decrease in the free swim, start, turn and finish times tended to be related to improved performance.

Table 5 Significant Correlations with Independent Variables in Breaststroke Races

Distance	Gender	Free Swim	Start Time	Turn Time	Finish Time	Stroke Length	Stroke Freq	Eff Index
100m	Male	**(0.71)	*(0.59)	*(0.53)	**(0.69)			
100m	Female	*(0.53)	**(0.76)	**(0.82)				
200m	Male	**(0.78)	**(0.62)	**(0.67)	**(0.73)			
200m	Female	**(0.97)		**(0.91)	**(0.61)	*(-0.50)		**(-0.69)

Breaststroke

MALES. In the 100m, free swimming time (0.71) and finish time (0.69) were significant at the

0.01 level while the start time (0.59) and turn time (0.53) were within the 0.05 confidence level. In the 200m, free swimming time (0.78), start time (0.62), turn time (0.67) and finish time (0.73) were significant at the 0.01 level. As previously shown, when the free swim, start, turn and finish times decreased, the race result improved.
FEMALES. In the 100m, start time (0.76) and turn time (0.82) were significant at the 0.01 level and the free swimming time (0.53) was significant at the 0.05 level. In the 200m Breaststroke, free swim time (0.97), turn time (0.91), finish time (0.61) and efficiency index (-0.69) were significant at the 0.01 level while stroke length (0.50) was significant at the 0.05 level. That is as performance improved the stroke length and efficiency index increased while the free swim, turn and finish times decreased.

Table 6 Significant Correlations with Independent Variables in Individual Medley Races

Distance	Gender	Free Swim	Start Time	Turn Time	Finish Time	Stroke Length	Stroke Freq	Eff Index
200m	Male	**(0.93)		**(0.81)				
200m	Female	**(0.94)	*(0.58)	**(0.89)				
400m	Male	**(0.96)		**(0.93)				
400m	Female	**(0.82)		**(0.86)				

Individual Medley
MALES. In the 200m, free swimming time (0.93) and turn time (0.81) were related at the 0.01 level of significance. Of the strokes, the Breaststroke free swimming speed (-0.89) was significant at the 0.01 level while the Freestyle free swimming speed (-0.49) was at the 0.05 level of significance. In the 400m, free swimming time (0.96) and turn time (0.93) were significant at the 0.01 level. That is as performance improved the free swimming time and the turn times decreased for both distances. Of the strokes involved, the Breaststroke leg (-0.82) was the only stroke that was significantly correlated (alpha level 0.01) with the race result.
FEMALES. In the 200m, free swim time (0.94) and turn time (0.89) were related at the 0.0l level of significance while the start time (0.58) was significant at the 0.05 level of confidence. Similar to the male results, as performance improved the free swimming time and the turn times decreased but the women also demonstrated a correlation with the start time decreasing. Of the strokes involved, the Backstroke (-0.59) and the Butterfly (-0.51) at the 0.05 level were significant. In the 400m, free swimming speed (0.82) and turn times (0.86) were significant at the 0.01 level of significance. This again showed the same trends as the male individual medley results where the turn time and free swimming time decreased with better race results. Of the strokes involved, the Breaststroke (-0.84), correlated with performance at the 0.01 level of significance while the Backstroke (-0.70) was significant at the 0.05 level of confidence.

Table 7 Significant Correlations for each Stroke in Individual Medley Races

Distance	Gender	Butterfly	Backstroke	Breaststroke	Freestyle
200m	Male			**(-0.89)	*(-0.49)
200m	Female	*(-0.51)	*(-0.59)		
400m	Male			**(-0.82)	
400m	Female		*(-0.70)	**(-0.84)	

DISCUSSION:
All Events. Free swimming time was correlated with race performance in every event at the 0.01 significance level except for the women’s 100m breaststroke but this still correlated at the 0.05 level. This result showed that free swimming time is a very important factor. As

would be expected, the free swimming component of the race was the largest single independent variable, meaning that there was a good chance that it would have a significant effect on the race result. The next strongest correlation with race performance was the turn time, which was shown to be significant in 92% of the races analysed. Stroke length and stroke frequency had very little influence on the race result in general and the efficiency index was shown to have a level of significance in 30% of the cases.

Freestyle. In the 50m sprint event for both genders, there was a significant relationship between the starting time, finish time and the race performance as would be expected in such a short event. The same relationship was also shown in the 100m race, with the inclusion of a correlation with the turn time. It was shown that the turn time was more significant in the men's race than the women's whereas the start time correlated more strongly in the women's race. Turn times and free swimming time were shown to have a high correlation with race results in the 200m Freestyle events for both genders. A significant relationship was found with the start time in the men's race while the finish time was shown to be highly correlated with the outcome of the women's 200m Freestyle. The 400m event for both genders showed a slight correlation with the start time, which was surprising in a middle distance race. The male 400m Freestyle also demonstrated significant results in stroke length and efficiency index but this may have been due to the makeup of the swimmers and the smaller subject number than used in the shorter distance races. There was also the usual strong correlation with the race performance and free swimming time and turn times for the 400m distance. The distance races (800m and 1500m) both showed slightly significant results with the finish time, which was not anticipated. Other contributing variables in the race result were free swimming time, start time (men's) and turn time. The only race that showed a significant relationship between the race performance and stroke frequency was the women's 800m Freestyle, which was interesting. Half of the Freestyle races showed significant correlations between the race result and efficiency index indicating that the combination of the stroke length with the velocity for each race interval was quite effective in these races.

It was interesting to note that the start time played such an important role in the outcome of the longer Freestyle races although you would expect this from the shorter events. Turn time was highly correlated in all events with a greater significance in the male events than for females. The one surprising result was the significance of the stroke frequency on race result in the women's 800m Freestyle. In general, the higher the stroke frequency, the better the overall race result but this may be due to the decreased kicking action in the longer races. This result was not seen in the men's 1500m race where a greater stroke length was deemed to be a greater contributing factor to the success of the individual.

The statistical analysis on the two halves of the longer races showed that the second half of the race was more highly correlated with race performance than the first half. It suggested that the second half of the race was more significant as the better performers were able to maintain faster free swimming times for a longer time period than some of the lower placed athletes. The exception to this was in the women's 400m race where there was no correlation between the second half of the race and the final outcome of the race. It must be remembered that in the longer races (400m and above) no semi-finals were contested which meant that the statistical analysis was only conducted on eight subjects.

Butterfly. The free swimming time, start time and turn time were significant factors for both genders in all races other than the men's 200m Butterfly where the start was not shown to be significantly correlated with the race result. There was a strong correlation with the efficiency index and race performance in the 100m event for both genders with a strong negative correlation between stroke length and race performance in the women's 100m Butterfly. Finish time was shown to be significantly correlated with race performance in the Men's 200m Butterfly.

Backstroke. As was shown in the Butterfly events, there was a strong correlation between the race results and the free swimming, start and turn times. The females also showed a correlation between the finish time and performance for both race distances. In the 100m Backstroke races, the greatest contributing factor was the turn time and this may be considered important when examining the length of time that swimmers spend in the underwater phase of the turn. The free swimming time was found to be more important than the turn times in the longer race for both genders but this is to be expected with a greater period of time spent swimming than turning. This might suggest that swimmers are unable to stay under the water for as long during each turn in the 200m race and this could highlight an area for performance improvement.

Breaststroke. The free swimming time and turn times were again shown to be highly correlated with race result in both the 100m and 200m events for both genders. The start time was shown to be significant in all events except for the women's 200m Breaststroke. The finish time was also shown to be highly correlated with the performance of the men's 100m Breaststroke and the 200m race for both genders. This result may highlight the need for a strong finish at the end of the race and for swimmers to make sure that the timing of their stroke from the flags into the wall is correct for a better race result. A small relationship was seen with the stroke length in the women's 200m event and a stronger correlation was seen with the efficiency index in the same race.

Individual Medley. Neither start nor finish times were shown to be significantly related to the race performance. Again the most important contributing variables to the race result were the free swimming time and turn times with a fairly even level of correlation. When the free swimming speed was divided into the different strokes, it was shown that the Breaststroke was the most influential in the final outcome of the race. This held true for all races except for the women's 200m Individual Medley where the Backstroke correlated slightly more than the Butterfly leg. In general, the order of importance to the race performance was Breaststroke followed by Backstroke, Butterfly and Freestyle. This would be the order generally found by most coaches and an athlete but is different to the results found by Mason (1999) where the Backstroke leg was found to be the most significant stroke at the 1998 World Championships.

CONCLUSION: It is a common perception of people within swimming circles that the single most important factor in a successful race is stroke length. It is thought that a swimmer with a longer stroke length than another competitor is more likely to be successful in the event. The analysis of the 1999 Pan Pacific Swimming competition analysis indicated that this perception is incorrect with respect to top level international swimmers. Turning performance was the most influential variable on race performance other than the free swimming time. Start and finish times were also significantly correlated in a majority of the freestyle races for both genders. The statistical analysis showed that the second half of the longer races (400m, 800m and 1500m) was more significantly correlated with the race result than the first half except for the women's 400m freestyle. Race performance in all of the form stroke events (Butterfly, Backstroke and Breaststroke) were related to the free swimming time as well as both start and turn performance. In the Individual Medley events, the turn time was significantly correlated to race performance for both distances and genders. In general, the order of importance of the free swimming for each of the strokes was Breaststroke, Backstroke, Butterfly then Freestyle.

Feedback from coaches and swimmers over the years has shown that all independent variables collected in the swimming competition analysis can relate to the overall race performance when dealing with a particular swimmer. It must be remembered that the swimmer's final performance is related to the coach's ability to determine the most effective competition model for the individual swimmer and that the appropriate training is used to attain this model during a competition. The competition analysis can be a useful tool in determining the most effective competition model for a particular swimmer both in and out of competition. At the completion of the race, the swimmer and coach can decide how successful the model was and if the athlete achieved what they set out to do originally.