*Coaching Applications*

# On the Fair Management of Close Races in Swimming

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**Abstract**

*The sport of swimming faces particular problems of adjudication for close races. Swimming cannot benefit from technology in the same way as athletics and other sports in which photo finishes and visual differentiation is used to determine ranking. Swimming at the highest level relies almost entirely on the electronic timing system and displayed race times, presented to the nearest 0.01s, to determine the ranking of swimmers and to establish if a dead heat has occurred. At swimming events, electronic timing equipment records individual race times to 0.0001s. However, it is shown that any protocol used to display race times to the nearest 0.01s leads to unfairness in the categorization of a race as a dead heat. The key issues are discussed in the context of the controversial Michael Phelps and Milorad Ĉavić 100m butterfly event at the 2008 Beijing Games. An alternative approach for the categorization of a dead heat is proposed which is fairer to swimmers.*

## Introduction

Precision timing at premier sporting events is normally achieved by fully-automatic timing systems with times presented to the hundredth or even thousandth of a second. When an outcome comes under scrutiny, higher precision post-event analysis confirms the result (5). A prime example of close-race management in sport is the use of the "*photo finish*" which is an integral feature of horseracing, track athletics, cycling, and a host of other high-level sports. The photo finish constitutes the "*holy grail*" in determining ranking and race time indisputably.

The world of swimming is at a disadvantage in this respect, since the use of a photo finish approach to the adjudication of close races is not practical due to the distortion of light through disturbed and aerated water. A photo finish system could not function at the level of accuracy required to distinguish placings and is not adopted even at the highest level of the sport. Swimmers finish a race by activating a timing pad and the automated operating equipment (AOE) records an electronic time which is used to determine the swimmers' race times. At the highest level of swimming competition, the electronic times are not questioned and it is each swimmer's responsibility to ensure that they complete the race by activating the timing sensor. Race times are presented to the viewing audiences on a digital display to 0.01s. If the times of two swimmers are identical on the display board, a dead heat is deemed to have occurred and the two swimmers are awarded the same ranking. Only in the event of failure of the AOE system are alternative methods used to determine the race time. These alternative methods usually involve a combination of backup timing, manual timing and rankings produced by place judges, with the referee holding the authority to determine the official race time.

Swimming is not without close-race controversy. The Michael Phelps and Milorad Ĉavić 100m butterfly event at the 2008 Beijing Games is one of the most famous races in Olympic swimming history. Michael Phelps won the gold medal (his record equaling seventh of the games) on the very last stroke and Milorad Ĉavić won the silver. The displayed times in the arena differed by 0.01s yet, from the spectator point of view, Ĉavić appeared to touch the timing pad first with slow motion action replays being inconclusive. The race time difference between the two swimmers did not appear to be as much as 0.01s to viewing audiences and questions were raised as to the validity and reliability of the AOE system for the determination of the outcome of close races.

The time it takes a swimmer to complete a race distance depends on several factors outside the control of the swimmer, including, for example, the consistency of the length of the pool in different lanes. Such factors have been discussed in some detail (see (5) and sources therein). But despite the reliance of the sport on the use of scoreboard-displayed race times in determining rankings and dead heats, there has been no discussion on the impact of the process by which the electronic race times are presented for display on the outcome of close races. In this article, we show that, regardless of the algorithm used to convert electronic times to display times, unfairness is inevitable. We show that Ĉavić could have simply been unfortunate not to have shared the gold medal with Phelps.

## The Principles Behind the Management of Close Races

Before examining the situation in swimming, we explore the processes by which athletes' rankings and times are determined in close races where outcomes can be determined without dispute. In athletics for example, a photo finish system is employed. Taking the 100m sprint as an example, flailing arms and legs could impact the accuracy of the recorded electronic time for a specific runner. The photograph, sometimes stretched, enables times to be awarded to athletes that fairly reflect the rankings. Indeed, the rules of the International Association of Athletics Federations (IAAF) are clear on how the process is managed: Rule 164.2 "*The athletes shall be placed in the order in which any part of their bodies (i.e. torso, as distinguished from the head, neck, arms, legs, hands or feet) reaches the vertical plane of the nearer edge of the finish line as defined above*." (6). The time is recorded on the photograph at intervals of 0.001s and the "*official time*" is based on robust photographic evidence and presented to the spectators and viewing audiences. Top sprinters cover 100m in about 10s and so, in 0.01s, travel 10cm. A separation of 10cm is clearly discernible in a photo finish. Indeed, a distance of 1cm, or 0.001s, between runners can be resolved from a photograph. Thus, the finish of each athlete can be aligned to a time that is precise to about 0.001s. Two runners might therefore be clearly differentiated in the photo finish yet obtain the same official time recorded to 0.01s. In such cases the photographic evidence supporting the rankings can be presented to viewing audiences enabling two athletes in a close finish to be ranked, without dispute, yet awarded the same official time to 0.01s. If two athletes cannot be separated visually, a dead heat is declared.

It is helpful to identify three distinct race times, and these are listed in Table 1. These are the raw time, the display time, and the official time. The *raw* time is the output from the digital timing device produced to the nearest 0.0001s for a quartz oscillator timer. The *display* time is the time presented to viewing audiences immediately after the race. The *official* time is the final approved time after additional evidence has been appraised. In the example from athletics, the additional evidence is the (possibly stretched) photograph which can resolve times to 0.001s. The IAAF Rule 165 23(a) states "*With photo finishes, for all races up to and including 10,000m, unless the time is an exact 0.01 second, the time shall be converted and recorded to the next longer 0.01 second, e.g. 26:17.533 shall be recorded as 26:17.54*." This rule acknowledges that photo finishes can resolve times to 0.001s and may be used to determine athletes' rankings, but that official times presented to 0.01s are never shorter than the higher-precision race time.

**Table 1: Description of race time terminology used in this article.**

| | **Description** |
|---|---|
| Raw time<br>**50.5897** | This is the time produced by the quartz oscillator of the timing device. The timing device counts the number of oscillations between start and finish signals and multiplies by a number to yield a time accurate to 0.0001s (about 3 oscillations). |
| Display time<br>**50.59** | The raw time is processed by timing device software to produce a display time that is presented for display to viewing audiences. The display time is normally presented to 0.01s (to 0.001s in Formula 1 racing). |
| Official time<br>**50.59** | The official time is normally identical to the display time. The official time may be adjusted by the appropriate authorities after due consideration of additional evidence such as photographs, by-eye rankings and/or race times from additional timing devices. |

Despite the clarity and robustness of the IAAF rules, controversy still arises (4). Nonetheless, sports such as track athletics that employ visual differentiation to obtain definitive rankings and times are fortunate. At lower levels of sport, such facilities may not be available and in many sports where close finishes are commonplace, photographic techniques are impractical even at the highest level. Swimming is one such example. Swimming employs electronic timing but no photo finish equipment. The AOE used in swimming competition produces raw race times to 0.0001s. The standard setting for display times (10) produces a display time to 0.01s that is never shorter than the raw race time. The official time is recorded to 0.01s and is the same as the display time, unless there is equipment fault, say an issue with the touch-sensitive pad. In the very unusual event of equipment fault, the referee will gather information from the back-up timer(s), manual timers and place judges to determine the official time.

Barring equipment fault, the Fédération Internationale de Natation (FINA) places total reliance on the AOE for timing (3). This is not without controversy as illustrated by the Michael Phelps and Milorad Ĉavić 100m butterfly event at the 2008 Beijing Games and Finn (5) provides an excellent discussion of the issues. Michael Phelps won the gold medal and Milorad Ĉavić won the silver with the display times in the arena differing by 0.01s. At race speed, an elite swimmer travels about 1.7cm in 0.01s (5). Readers are encouraged to view the video evidence for themselves (11). The eye struggles to determine which swimmer touched the pad first. It is not clear that the distance between the swimmers is as great as 1.7cm. No clear photographic evidence has been made public, to our knowledge, to confirm that Phelps touched first and the raw race times recorded by the AOE (accurate to 0.0001s) were not available.

The focus of the post-race discourse, especially amongst journalists (1, 2, 7, 9), was on the contradiction between what the eye apparently saw and what the electronic timing system recorded. At the time, the head of FINA and the race referee both stated that it was clear that Ĉavić was second. Boswell (1), who reported that FINA allegedly studied replays at 0.0001s, confirmed that "*There are no doubts: it was very clear that the Serbian swimmer touched second.*" By contrast, Saletan (9) summarizes contrary evidence that Ĉavić touched the pad first. Finn (5) reports that Omega (the official timers for the 2008 Beijing Olympic Games) issued a press statement after the controversial race explaining their timing technology and noting that "*their timing and imaging systems provide rankings which are beyond doubt and dispute.*" Years later the race still provoked controversy with Mark Spitz, whose gold medal tally record Phelps beat, claiming that he had seen an email from Omega which proves that Phelps had lost the race (8).

Saletan argued that it is irrelevant who touched the timing pad first (9). The electronic timing does not stop at this moment. It is the swimmer who *activates the sensor* first who wins the race. Ĉavić clearly did not activate the pad sensor first. Ĉavić drifted slowly to the timing pad compared to Phelps' hands which were moving rapidly during his final half-stroke. But let us probe the science of the argument a little further. The pad is 12mm thick and to activate the sensor the pad needs to be moved 2mm with a force of 1.5-2.0kg to close the contact (11). The swimmers were travelling at about 1.7m/s and so it takes each swimmer about 0.0012s to travel the 2mm to close the gap. Even with Phelps' greater hand speed at the final stroke compared to Ĉavić, the time made up by Phelps during the sensor activation process would be less than 0.001s. In addition, Finn points out that tolerance of the length of a 50m pool allowed by FINA rules is 3cm. This distance is greater than the 1.7cm moved by the swimmers in 0.01s so that providing rankings and determining dead heats by using race times presented to the nearest 0.001s would be unjustifiable. The discussions emerging from the Phelps-Ĉavić encounter are interesting and relevant, and the excellent discourses of Finn (5) and Saletan (9) highlight the relative importance of many of the points made from a technological standpoint.

The video evidence (11) makes it clear that the installation of a photo finish system is unlikely to have helped confirm the outcome of the Phelps-Ĉavić race. Images would be distorted by the presence of the water and the movement of water in the vicinity of the swimmer's hands and the touch-sensitive pads. Thus, the deployment of a photo finish system is unlikely to help determine the ranking of swimmers in close races. Despite the numerous discussions and protestations about the outcome of the Phelps-Ĉavić race, there has been no discussion as to the impact of the *process by which race times are displayed* on the possible outcome of close races. It is the *display* times in swimming that determine the rankings of swimmers (hence medals awarded) or whether a dead heat has been deemed to occur because the *display* times are taken as the *official* times. This reliance on the display times for determination of race position is now discussed in detail.

## Close Races – Impact of Display Presentation

We now comment on the potential impact of the presentation of race times in the context of close swimming races where photographic evidence is not available. The AOE timing at swimming events records the swimmers' raw race time to 0.0001s (about 3 ticks of the quartz oscillator). Software then translates the raw race time to a display time to 0.01s on the scoreboard in the swimming arena and this is accepted as the official time except in exceptional circumstances.

The FINA rules and regulations on the management of dead heats is as follows: SW 11.2 "*When Automatic Equipment is used, the results shall be recorded only to 1/100 of a second. In the event of equal times, all swimmers who have recorded the same time at 1/100 of a second shall be accorded the same placing. Times displayed on the electronic scoreboard should show 1/100 of a second.*" (3). Thus, a dead heat is declared if the displayed times are identical. This is confirmed by regulation SW 13.4.2 "*If a swimmer has an official time which is tied with the official time(s) of one or more swimmers, all swimmers having that time shall be tied in their relative order of finish in that event.*" Note the use of "official" time in the second regulation.

Now consider the process which converts a race time measured to 0.0001s to a displayed time given to 0.01s. To ensure that an official race time is no shorter than the raw race time, raw race times are rounded up. For example, a raw race time of 50.5800s will display as 50.58s, and a raw time 50.5801s will display as 50.59s (10) as illustrated in Fig. 1. A comparison of these display race times shows that two swimmers with raw times that differ by only 0.0001s can be recorded with race time differing by 0.01s and given consecutive race positions, conversely a dead heat can be called between two swimmers despite their raw times differing by nearly 0.01s.

**Figure 1.** Fictional raw race times for eight swimmers are presented. The official time for each of the current system and proposed delta-*t* method is displayed with **D** indicating a dead heat. The delta-*t* method is demonstrably fairer to athletes. For example, Wei Kwik is ranked first ahead of Sinka using the current system despite only being 0.0001s faster. The proposed delta-*t* method fairly has Wei Kwik and Sinka as a dead heat with Fast in third place with the same official time.

| | raw time | delta |
|---|---|---|
| Wei Kwik | 50.5800 | |
| | | 0.0001 |
| Sinka | 50.5801 | |
| | | 0.0098 |
| Fast | 50.5899 | |
| | | 1.0041 |
| Poole | 51.5940 | |
| | | 0.3965 |
| Overley-Whett | 51.9995 | |
| | | 0.0007 |
| Splatt | 52.0002 | |
| | | 0.0040 |
| Speedie | 52.0042 | |
| | | 0.0013 |
| Goode-Turner | 52.0055 | |

Current system

| | | | |
|---|---|---|---|
| 1 | Wei Kwik | 50.58 | |
| 2 | Sinka | 50.59 | D |
| 3 | Fast | 50.59 | D |
| 4 | Poole | 51.60 | |
| 5 | Overley-Whett | 52.00 | |
| 6 | Splatt | 52.01 | D |
| 7 | Speedie | 52.01 | D |
| 8 | Goode-Turner | 52.01 | D |

delta-*t* method

| | | | |
|---|---|---|---|
| 1 | Wei Kwik | 50.59 | D |
| 2 | Sinka | 50.59 | D |
| 3 | Fast | 50.59 | |
| 4 | Poole | 51.60 | |
| 5 | Overley-Whett | 52.01 | D |
| 6 | Splatt | 52.01 | D |
| 7 | Speedie | 52.01 | D |
| 8 | Goode-Turner | 52.01 | |

Note that the process used to reduce the raw time to a time to 0.01s is irrelevant - whichever algorithm is used poses a problem of rounding. Any algorithm can take two raw race times differing by less than 0.01s and produce display times separated by 0.01s or, conversely, display these as a dead heat with identical display times. To illustrate and re-emphasize, suppose that Phelps activated the pad sensor 0.0050s before Ĉavić. Suppose Phelps' *raw* time was recorded as 50.5760 and Ĉavić's time as 50.5810. With these two race times, the display times, according to the standard procedure, are 50.58 and 50.59 respectively, exactly as displayed at the 2008 Olympics, and Phelps wins. Consider now a different scenario in which the raw times are 50.5750 and 50.5800. Each *individual* raw race time is less by only 0.001s than the previous individual time yet the displayed times are now both 50.58 and the race is declared a dead heat. If the AOE provides the same winning time for two lanes in an Olympic final, the rules for a dead heat leads to shared gold medals. It is quite possible that Ĉavić was unlucky not to have shared the gold medal with Phelps. Should medal outcomes be determined by luck?

We note that at lower levels of swimming, for instance at club competitions, there is less reliance on the display times. The display race times are *unofficial* times until confirmed by the referee. The AOE operators often have the additional responsibility to alert the referee to a timing issue, such as a missing electronic primary time or a significant time discrepancy between primary and secondary (back-up) times. The referee then seeks additional evidence from officials who undertake backup and manual timing, and from place judges whose role it is to provide the rankings of swimmers. The rankings are then compared with the display race times from the AOE. Occasionally, place judges may clearly identify that swimmer A touched ahead of swimmer B, yet the electronic race time indicated otherwise. The referee has the authority to change the race time of swimmer A. This is commonplace in competitions with young swimmers who may clearly be seen to touch the timing pad but too gently to activate the pressure sensor. Fairness to the swimmers dictates that adjustments to the unofficial electronic time displayed on the scoreboard may be required. An adjusted official time may be announced to the audience if it differs from the time originally displayed on the scoreboard.

The discussions prompted by the Phelps-Ĉavić race focused on whether the first two places were correctly allocated. It is our view that attention should instead focus on the fairness of dead heat rules in swimming. We identify three processes by which the close races can be managed in line with current technology.

## Close Races – Management Options

Three processes for management of close races are discussed in detail in the full companion paper and are summarized here:

1. Retaining the current system

In the current system, raw race times are displayed to 0.01s and these display times are used to determine whether or not a dead heat has occurred. This approach has the advantage of clarity and speed because no separate processing is required beyond presenting the race times to 0.01s. However, the determination as to whether a close race constitutes a dead heat can be demonstrably unfair to the athletes. Two swimmers with race times that differ by nearly 0.01s can have the race recorded as a dead heat, so both receive a gold medal. Conversely, another two swimmers can have raw times differing by only 0.0001s with the display showing a difference of 0.01s – no dead heat and silver and gold medals awarded. This is illustrated in Fig. 1 by swimmers Wei Kwik and Sinka.

2. Use of the raw times to avoid dead heats

The AOE system at swimming competitions is capable of recording race times to an accuracy of 0.0001s. These raw times could, in principle, be used to determine rankings and medals. This would virtually remove the possibility of a dead heat and swimmers would receive individual distinct rankings, even if they had identical display times.

While the technology can deliver the rankings, the issue is whether it is reasonable for two swimmers with very close race times to be ranked with such high precision. Can the authorities be certain that the precise time it takes a pulse signal to travel from the timing pads to the AOE is the same to 0.0001s regardless of lane? Should the time taken between the touch of the pad and the activation of pressure sensor be a significant factor in the timing process? Are the lengths of each lane the same to sufficient precision? In summary, is it fair and reasonable in the sporting arena to separate athletes for awards by margins is fine as 0.0001s? This question has been discussed by Finn (5) who raises many objections to reaching decisions about rankings by increasing precision of race times.

3. The delta-$t$ method

We argue for the consideration of an alternative basis on which to categorise a dead heat in swimming competitions that would be fairer to athletes. We propose an approach that goes some way towards reducing the element of luck in display times that might fall one side or another of a boundary of a relatively crude partition of time into lengths of duration 0.01s, but without generally discriminating between times that differ by the smallest time increment possible from the AOE. We recommend that a time *difference* between two raw race times, $\delta t$, is specified, below which a dead heat can be deemed to have occurred. For illustration, we specify $\delta t = 0.0050$s. The delta-$t$ method would be fairer for athletes and make better use of the timing technology.

The principal behind the method is that, in general, if two consecutive finishers have raw times differing by no more than 0.005s then the delta-$t$ method calls a dead heat. Otherwise, if the raw times differ by more than 0.005s, the swimmers receive consecutive rankings. On average, in 75% of the cases in which the first two swimmers have identical *display* times (to 0.01s) using the current system, the raw time difference will be no more than 0.005s and a dead heat declared. Thus, in this situation the delta-$t$ method yields the identical outcome to the current system, both approaches produce a dead heat. However, in the remaining 25% of cases in which the first two swimmers have identical display times, the raw time difference will exceed 0.005s – a dead heat will be recorded with the current system but not with the delta-$t$ method.

Also, the delta-$t$ method allows swimmers with *display* times that would differ by 0.01s under the *current* system to have a dead heat called if their raw race time difference is no more than 0.005s. In such instances, the times of the two swimmers sent to the display scoreboard (to 0.01s) would be the longer of the two display times.

A fine-tuning feature of the delta-$t$ method caters for the situation in which the raw times for a set of three or more finishers are such that the times of each consecutive pair differ by no more than 0.005s – see the companion text for full details. Official times and rankings are determined working through the finishers in order of increasing raw time. Within any set of two or more competitors awarded a dead heat, the official time sent to the display scoreboard (to 0.01s) is the slowest display time of the members of the set, in accordance with the policy in all sports that a competitor may not be awarded an official race time faster than their higher-precision time.

We illustrate the method by reference to Fig. 1 which shows eight swimmers listed according to raw time. The rankings and indications of dead heats are shown for both the current procedure and the delta-$t$ method with $\delta t = 0.0050$s. Full details on how the official times and rankings are arrived at for the delta-$t$ method are contained in the companion text.

We consider that the delta-$t$ method provides a consistent and fairer approach to the categorisation of dead heat than the current approach, since any competitors with a dead heat will have raw times differing by no more than delta-$t$. By contrast, with the current system some competitors with raw times differing by almost 0.01s are declared to be a dead heat (see Sinka and Fast in Fig. 1) and in some instances very small differences in raw times determine ranking (see Wei Kwik and Sinka in Fig. 1).

**Summary and Conclusions**

This article considers the impact of the presentation of race times in fully-automated electronically-timed swimming events for the management of close races. We agree that the activation of the timing pad sensor should conclude the swimmer's race and we agree that electronic timings must be used to determine dead heats. We also agree that display time should be presented to 0.01s to viewing audiences.

We show however that any algorithm used to produce display times and the policy of using these displayed times as a criterion for a dead heat leads to unfairness. Its impact is discussed in the context of the famous Phelps-Ĉavić 100m butterfly event at the 2008 Beijing Olympics in which Phelps secured his seventh gold medal by a margin of 0.01s in what appeared to be a remarkably close finish. The AOE systems record times to the nearest 0.0001s and correctly ranks swimmers on this basis. But the process of producing the scoreboard display times and the policy of using identical displayed race times as the criterion for a dead heat means that a dead heat could be declared when swimmers' times differ by nearly 0.01s or, conversely, allow swimmers with times that differ by just 0.001s or less to appear on the scoreboard with a time difference of 0.01s.

We provide three alternative procedures for managing close races in swimming. It is our view that it would be fairer for athletes for swimming governing bodies to specify a *time difference* below which a dead heat is deemed to have occurred by using the available raw race times produced, but not displayed, by the AOE. For example, we propose that the criterion that a time difference of 0.005s or less between two racers is classed as a dead heat should be considered. This would bring ranking in swimming competitions more in line with athletics competitions where track athletes rankings can be differentiated by time increments as small as 0.001s.

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