Using Predictive Modeling of recent swim performances and swim records to Assess the Impact of the newest generation swim suits on Competitive Swimming

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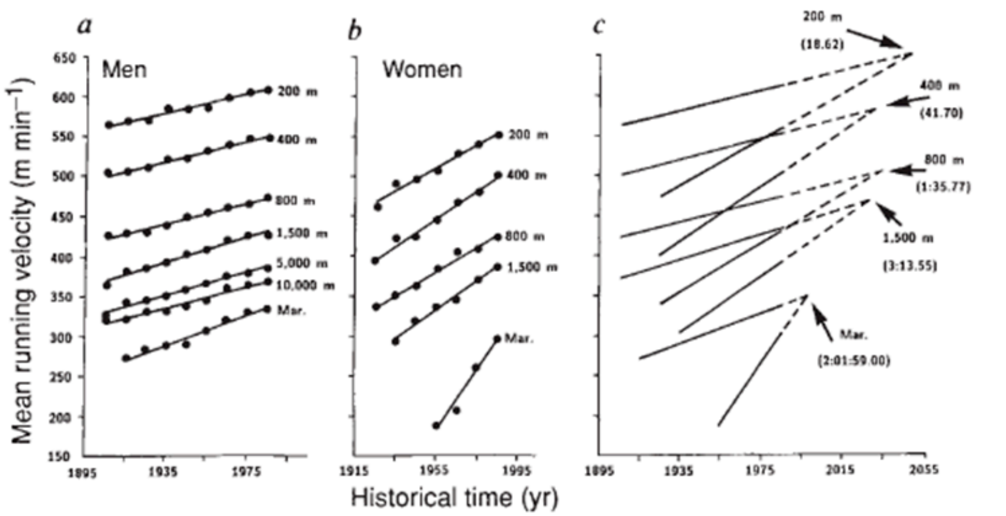
Rationale & Background:

The causes and or reasons for the recent multiple world and Olympic records in competitive swimming are of interest to both the general public and scientific community. Many relevant questions remain unanswered. Why now? Is this an unusual occurrence and are the records really being set at an unprecedented rate? If so, how do we know this is really different from what usually occurs during any Olympic year? Could this occurring as a matter of significantly better talent or better training techniques? How much faster can the records get? Maybe the records are as result of new coaching techniques or enhanced nutrition? Or, is the technology associated with the new swims suits assisting swimmers in a manner that prior to now did not occur? As usual, the questions are much easier to pose than is the process for finding the correct answers to them. There may, however, be existent evidence already available that helps shed light on this 'record setting' observation.

In the past, scholarly interest in the prediction of the boundaries of human performance has largely focused upon performance in running events. Similar to swimming, there is very little technology involved in competition and required by the track athlete beyond a pair of shoes. Initial analyses in track, as a means to predict future performances, relied primarily upon linear regression models to predict future athletic records. Criticism of this approach include the observation that linear models do not allow for an'ultimate limit' to human performance. Eventually, given enough time, the linear models predict "humans will run negative world record times" (Nevill and Whyte, 2007). While this is clearly absurd, linear models of performance do not allow or accept that there may be physiological, anatomical and biomechanical limitations that simply cannot be overcome by better training, more practice or better protoplasm.

Neither do these early linear models take into account improvements in such factors as nutrition, coaching knowledge, sociological and or economic factors that might influence performance (in either direction). Finally, linear models do not account for the fact that the characteristics of the competitors and competition used to generate the model may influence the slope of the generated progression line. If the sport has only recently been introduced it stands to reason that the rate of improvement will be greater early on as compared with that observed twenty or thirty years later simply as a matter of the sport itself approaching maturity. For example, one analysis of women's events suggests that their performances are improving at a greater rate than are the men's (Whipp and Ward, 1992). As a result, linear analysis suggests that eventually, in some events, the women's records will eclipse those of the men (Figure 1). While not impossible, it is more likely that the relationship is not linear and that with time the rate of improvement in women's records will slow and become similar to that seen in the progression of the men's records.



World record progression, expressed as mean running velocity versus historical time, for men (*a*) and women (*b*), with best-fit linear regressions (solid lines) superimposed. In *c*, the regression lines for the common events for men and women (solid lines) are extrapolated (dashed lines) to their points of intersection; the predicted world record times at these intersection points are shown in parentheses (h:min:s)

Figure 1. From: Whipp & Ward. (1992). Will Women soon outrun Men? *Nature, 355*, 25.

Human movement in the water, i.e., swimming, in many ways is a more complicated athletic performance to understand than is running. This is due, in part, to our current inability to fully understand and explain the fundamental biomechanics of swimming. Because of the complex nature of the relationships between propulsive forces and resistive forces in the water the mechanisms that allow humans to move at speeds in excess of two meters a second are, as yet, only partially described. Nevertheless, statistical analysis of swim performances can be performed in a manner similar to what has been done in running with the singular reasonable assumption that there is a limit to how fast a human can swim over a set distance.

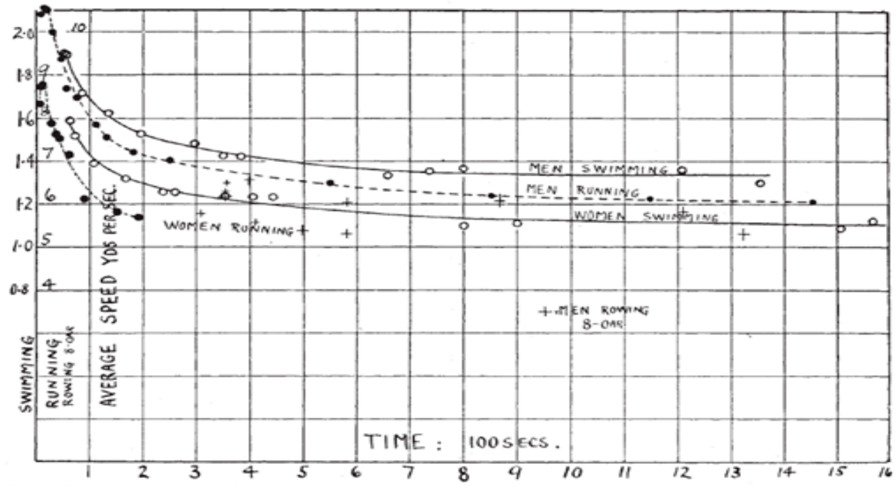


FIG. 1.—World's records for men and women swimming and running: average speed in yards per second against time in seconds. *Note.*—The scale for swimming is five times as great as for running. The observations for men rowing an eight-oar boat are on the same scale as running and are referred to later in the text.

Figure 2. From Hill,A.V. (1925). The physiological basis of athletic records. *Nature, 116*, 544-548.

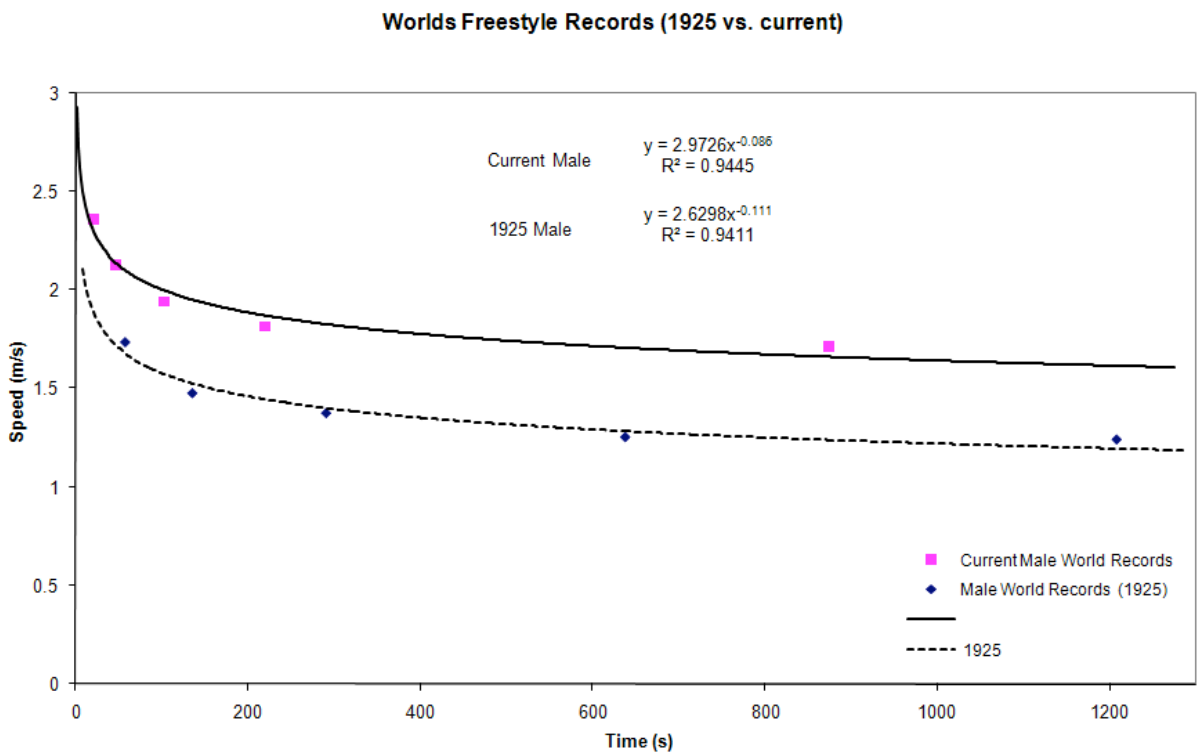


Figure 3. Recreation of Hill's graph of swimming speed vs. performance time. The solid line represents the current limits to freestyle swimming, whereas the dashed line represents records from 1925. The slopes of the two lines are not significantly different suggesting that the same fundamental physiological limitations exist today as compared to nearly a century ago.

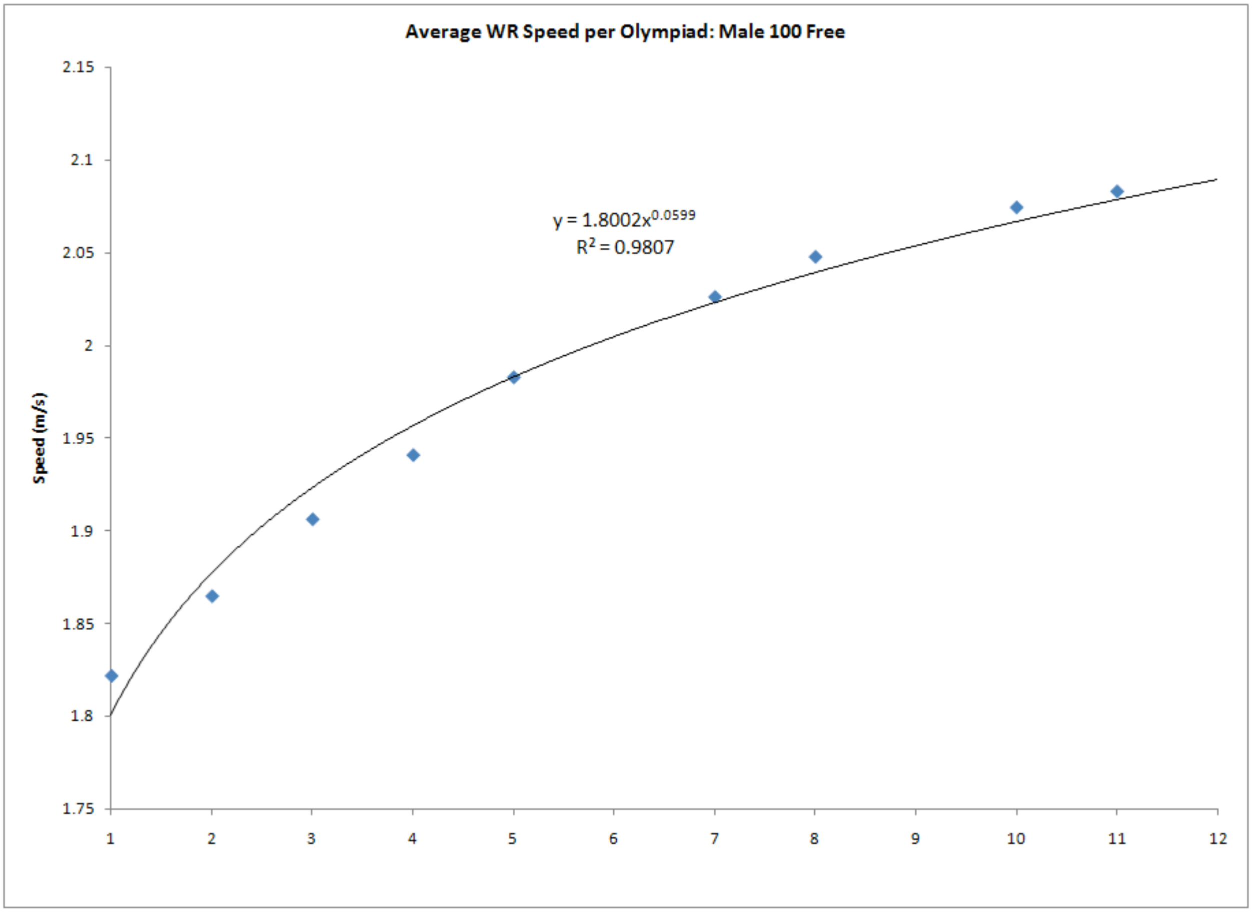


Figure 4. Illustration of the rate of change of world record speed in the 100 meter freestyle (meters/sec) for men in a fifty-meter pool. This demonstrates the curvilinear nature of the relationship. The x axis represents Olympiads being with 1960 (1) and continuing until 2000 (11). No records were set in the 100 m between 1977 and 1980, 1989 and 1992 and between 2001 and 2004 (missing values for 6, 9 and 12 on the x axis). The point being, as time goes by, the rate of change in record time is expected to be less and less as the limits of human performance are approached.

Performance in any athletic event is multi-factorial in nature. In the early twentieth century Hill described potential common variables and proposed that common factors contribute to performance in many sports and in both sexes (Figure 2). Nearly a century later, the nature of these relationships appears to be unchanged with no escape from limiting factors evident (Figure 3). As the required endurance (or rather length of the athletic event) increases the speed at which an athlete can perform it necessarily decreases. At any given event length, however the progression or improvement in performance (over the years) has not appeared to disproportionally change. Distance athletes do not appear, for example to have improved to a greater extent than sprint athletes. The data presented in Figure 1 tends to support this conclusion as well as that in Figure 3. Figure 4 represents the improvement in swim speed in one representative event, the men's 100-meter freestyle, when time is represented as speed (meters per second) as a function of 'longitudinal' time (years or this case Olympiads). The values provided represent the average speed of all of the records set *within* an Olympiad quadrennial. Thus, although the first person to swim faster than two meters per second for 100 meters did so in 1976 (Jim Montgomery, USA) the mean value for record speed during that Olympiad was somewhat less than two meters per second. This relationship can also be represented as simply date vs. event time (in seconds) as shown in Figure 5. The point to this is to simply demonstrate that there has been a non-linear, longitudinal progression in performance that can be illustrated such that 'non-conforming' data should be easily identified. As such, data can be identified as being statistically 'inconsistent' with the all of the preceding data (swim performances) and or subsequent data.

Once more, one caveat to any mathematical analysis of swim performance (and subsequent predictions of swim performance) based upon prior performances, is to accept that undefined and confounding variables may introduce biases into the analysis and potentially perturb the ability of any subsequent model to be accurate. For example, documented use of performance enhancing pharmacological compounds during the early to mid 1970's causes an overestimation of the rate of potential improvements in subsequent years. In other words, performances subsequent to this era will appear as if something has caused a slowing of the progression rather than the "return to a normal 'unbiased' progression". As time goes by, however, additional performances will 'correct' the model allowing for earlier truly biased performances to be obvious. The causes of the temporary perturbations will, however, be speculative, at best, until reinforced by historical confirmation.

The new technology or 'equipment' suits

In this regard, modeling performances on past competition outcomes might allow insight into one current controversy in the competitive swimming. The newly introduced "body suits" pit swimming purists directly against commercial financial interests. The debate centers on the introduction of high technology (and high expense) swim apparel into swim competition. Until recently the regulatory concern within the competitive swimming community was to enforce the rules that insured enough coverage in a swim suit worn during competition as to be socially acceptable. The newest generation suits eliminate this problem by covering the majority of the skin surface with reputedly 'low resistance' fabrics and materials. Due to the nature of commerce and claims of "proprietary" knowledge, very little specific data exists identifying the magnitude (if any) of the effect of these new suits on swim performance. Because of the existent rules in swimming limiting the use of technology to improve performance or alter buoyancy, commercial marketing of these suits is limited to inferences about the improvements in performance rather than any specifics. It is reasoned that the influence of the new high-tech suits can be measured if mathematical models based upon swim performances prior to their introduction are sensitive enough to do so. Interestingly, because none of these new suits existed prior to 2000 and it is possible to document when newer versions have been introduced, the athletes and their performances can be used to test to see if these suits have introduced unnatural rates of improvement into the sport.

In this way, it should be possible to answer the question as to whether or not the new 'equipment' suits violate the underlying principle of fairness within the sport. Do the suits represent a bias in performance? If so, are they doing so by violating the rules of competition in that they alter buoyancy or assist performance in some other way. Identifying a bias in the outcomes of performance as gauged by testing a valid model is a necessary first step before asking how it is that the suits alter competitive performance.

The following manuscript is divided into several sections: an analysis of current world records in swimming; an analysis of the effect of the Olympic quadrennial on the pace at which records are set in swimming; an analysis of the Japanese swimmers at their trials and the 2008 Olympics; an analysis of the performances of swimmers at the USA Swimming Olympic Trials; and an analysis of the performances of swimmers at the Olympic Games. From this we hope to identify unusual performances and determine whether or not (un)specified biases have influenced the performances of the field of competitors and the Olympic Games themselves. In other words, is there evidence to suggest that there has been a recent bias introduced into swimming that has significantly altered the progression of times in an unnatural way?

Part I The incidence rate and prevalence of Swimming Records.

The initial question at hand is whether or not the pace at which world records in swimming are set has recently accelerated. We recognize that, theoretically speaking, it is difficult to predict when and by what margin a world record will be set in any sport. This is because world records are, in effect, anomalous events. They represent performances beyond that which has been previously achieved and, thus, by their very nature are difficult to anticipate and predict. A number of authors, beginning as early as the first quarter of the last century, have concluded that athletic performances tend to improve over time and do so in a relatively predictable manner. They described world record performances, not necessarily by any given individual, rather, by the field of competitors. What has generally been observed is a gradual flattening of improvement rates as a sport "matures" and as competitors approach the limits of performance (presumably) within that sport or event. Figure 5 represents one example of the rate at which records in one swim event have changed over the last several decades. This phenomena, however, appears to be true for all swim events and in many, if not all sports, unless rules, technology, environmental or other changes or biases are introduced.

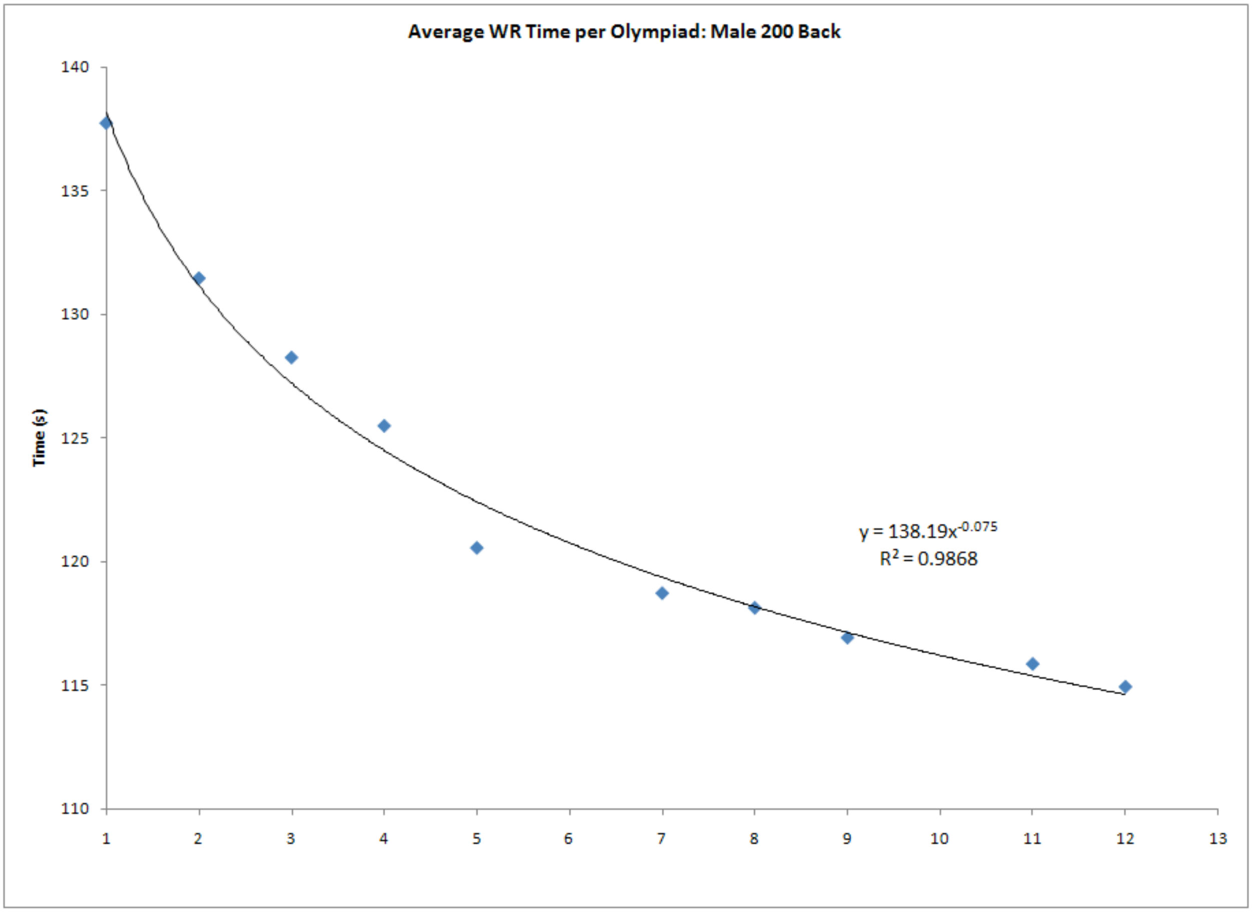


Figure 5 . The improvement in world record performance in a single event (the 200 meter backstroke) from 1960 to 2004 (1 through 12 on the x-axis respectively). Swim time is recorded as the average of the world records set during that Olympiad. If no record in this event was set during that time frame, no value is recorded.

From Figures 4 and 5, as examples, it can be seen that the rate of change (beginning nearly 50 years ago) declines as an exponential function when taken in whole. If we were only to use data from the last two or three quadrennials the decline in performance times appears to become nearly linear and virtually flat. The point to be made is that the decline in world record times can be described mathematically and that the rate of change generally decreases with time. Importantly, the rate of improvements in swimming records, in general, can be shown to have slowed (as they should), with this analysis used as part of the confirming evidence.

What is not apparent from these graphs is the frequency at which records have been set during any time span. For example, as the limits to backstroke performance are reached, it is hypothesized that the frequency at which the records might be set becomes less and less. Not only will the incremental improvement in record time become less and less, new records will become less frequent. Again, this observation should be true for any given event perhaps in any sport.

In swimming, in particular, a decline in the number of records and a decline in the magnitude of the improvements in the records are both likely over time because of the nature of the relationship between resistive forces and swimming velocity. This relationship is not linear; drag forces increase exponentially with an increase in velocity. Thus, to swim faster becomes increasingly more difficult as the required propulsive forces must increase exponentially also thereby mirroring the exponential increase in these resistive forces. The exceptions to this are rule changes reflecting unusual innovations within the sport. If a rule change occurs (after an innovation such as the underwater dolphin kick), it may be possible to perceive alterations in the rate of improvement as a result. However, the rate of change may be only a short offset that quickly reverts to a slope similar to that which existed prior to the rule change.

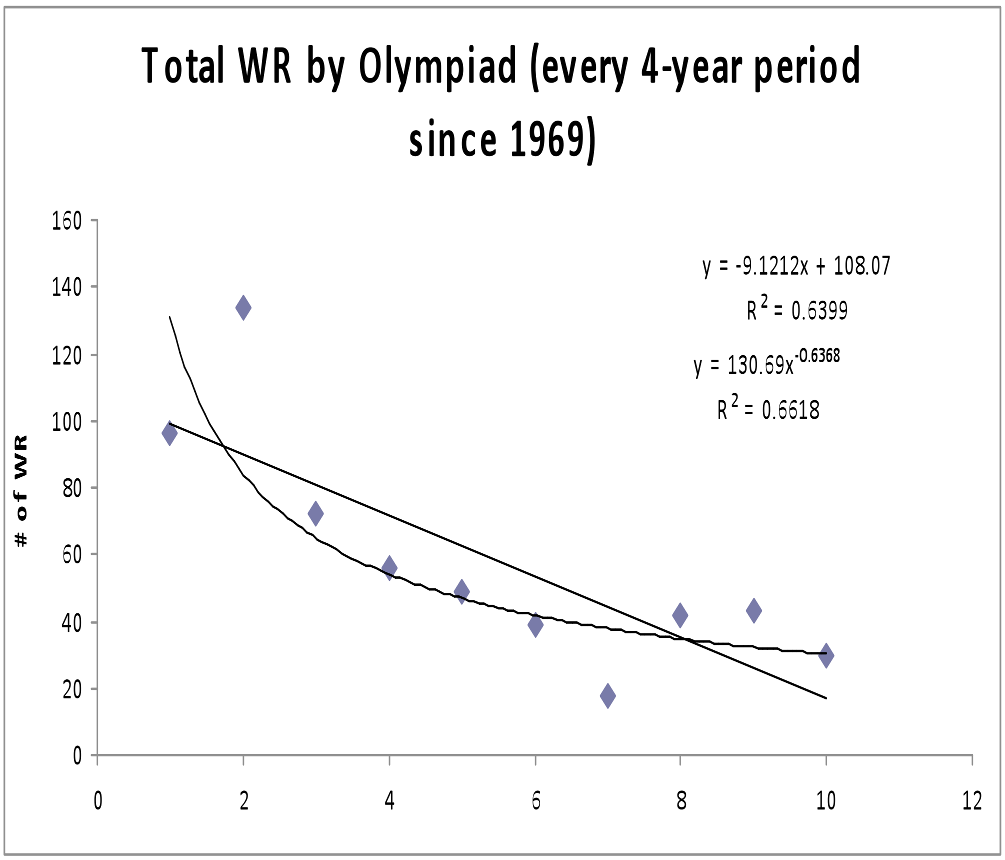


Figure 6. World records during each Olympiad from 1968 forward until 2004.

Figure 6 illustrates the number of world records achieved during each Olympiad beginning in 1968 and continuing until 2004. This suggests that the rate of change (as a function of simply the number of occurrences) is similar to that observed within a single event (Figure 4) and appears to be slowing at a relatively predictable rate. within the last 24 years (about forty per quadrennial). A noticeable bias does occur during 2008 (Figure 7) with more than forty records set this year alone. This bias affects the curve and ultimately reduces the strength of the relationship presented. The specific explanation for this bias is unclear. However, a closer look at the previous data provides some further insights. Figure 7 shows more clearly the impact of 2008 in that the number of records is nearly double that of the average in the preceding thirty years.

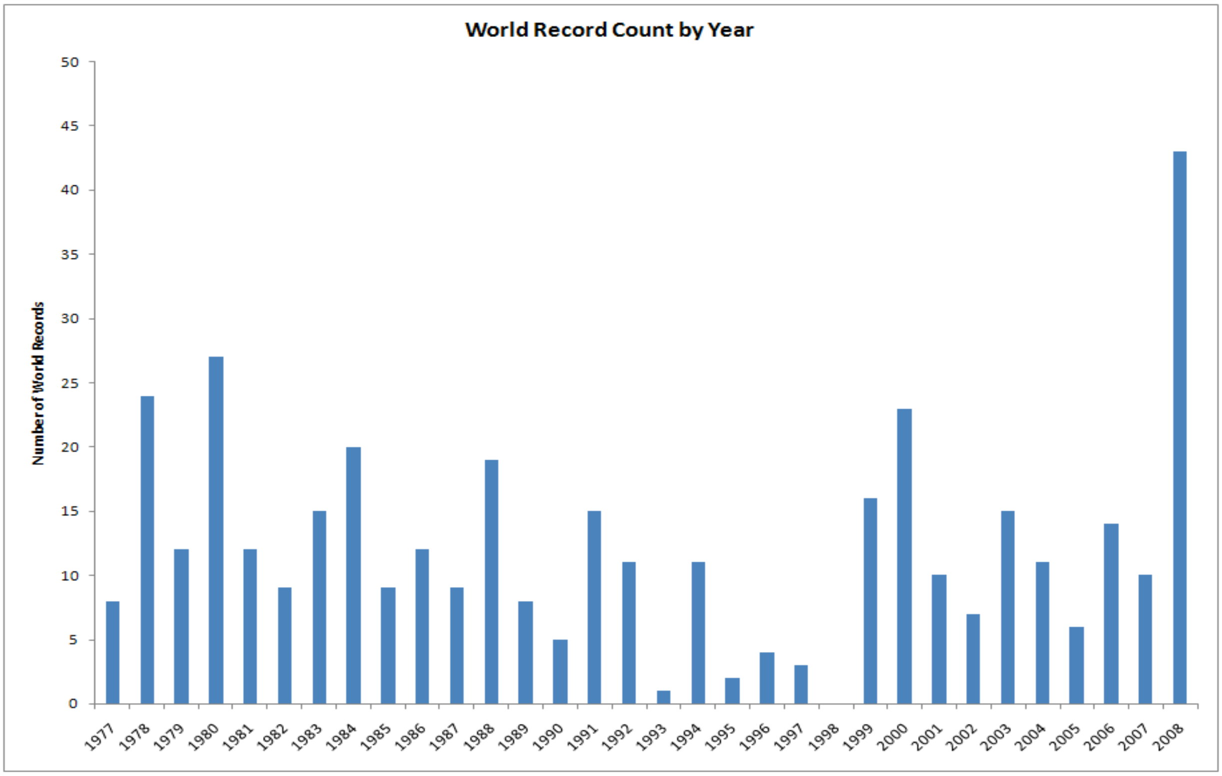


Figure 7. Frequency of world record performances per year (1977-2008). The number of records set in 2008 is nearly double that of the average for the thirty preceding years.

In the past 30 years (1977-2007), when the number of world records broken during an Olympic year is compared to the other three years it is not significantly different. However, statistically, the main effect for year approaches significance ($F_{3,367}$=2.37, P=0.07) and regression analysis indicates a significant linear trend (P=0.05, 0.92 R^2). That is, there is an increase in the number of world records at a constant rate across each of the three years prior to the Olympic year or, as the Olympic year approaches the number of new records increases year by year (Figure 8). It is also true that the rate at which records are set declines the following year with another gradual yearly increase until the next Olympic calendar year (Figure 9). This is a “paired comparison whereby the Olympic year is compared only to the immediately following year.

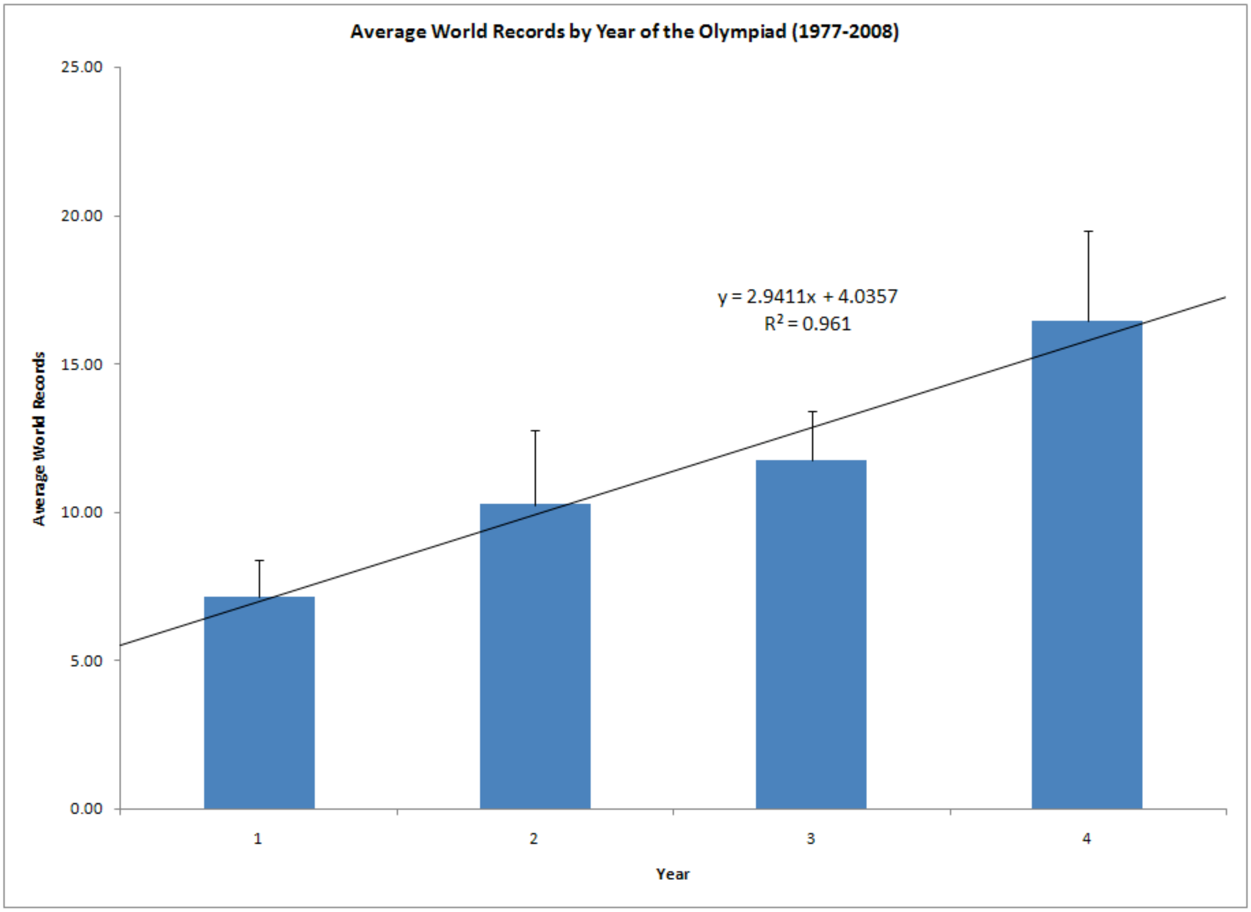


Figure 8. There is trend evident in the numer of world records as a function of year within the Olympic Quadrennial. A significant linear relationship suggests that the number of records increases by nearly 300% from the year after an Olympic Games to the year of An Olympic Games.

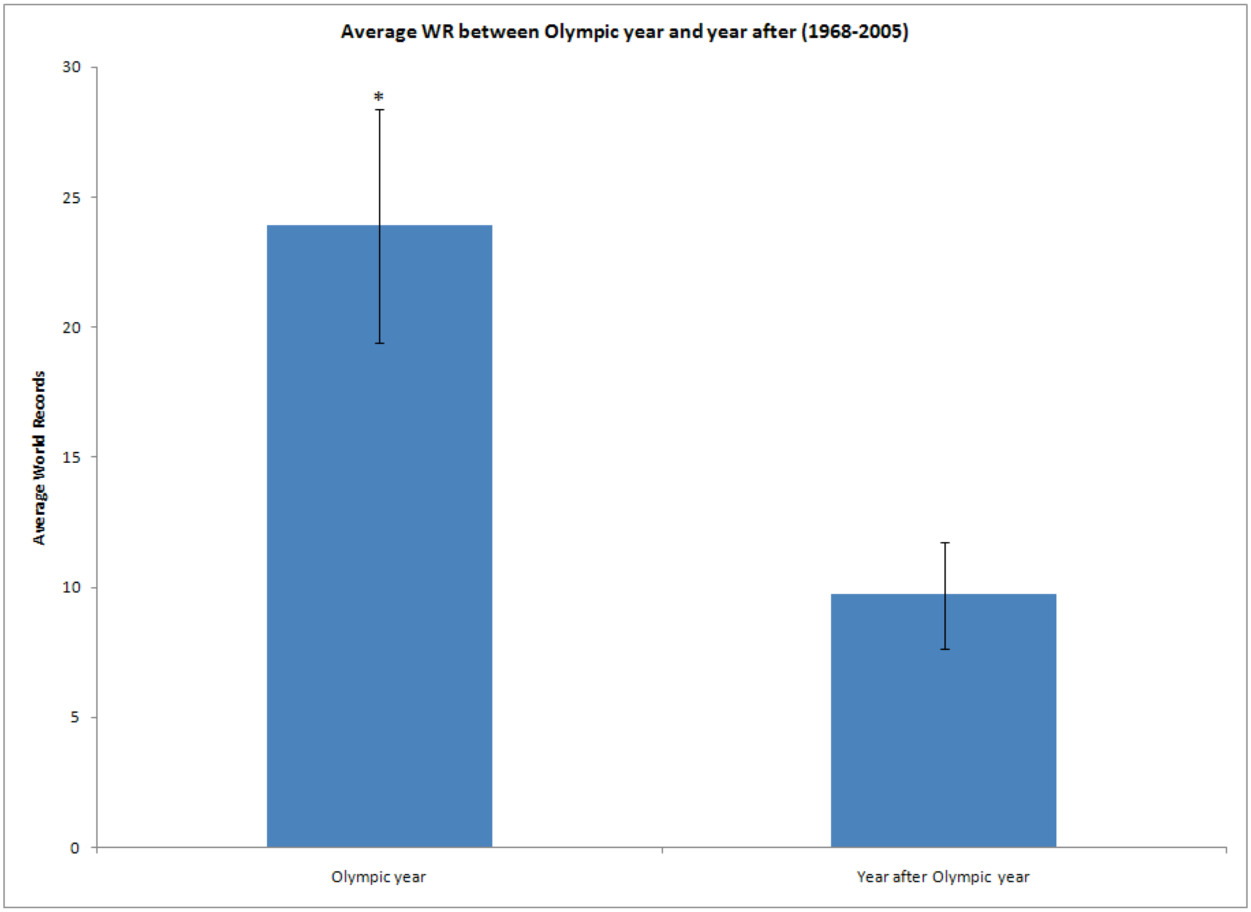


Figure 9. The decrease in world record performances in swimming during the calendar year following the year in which the Olympic Games were held. This comparison is a “paired” comparison where any given Olympic year is compared only to the immediately following year.

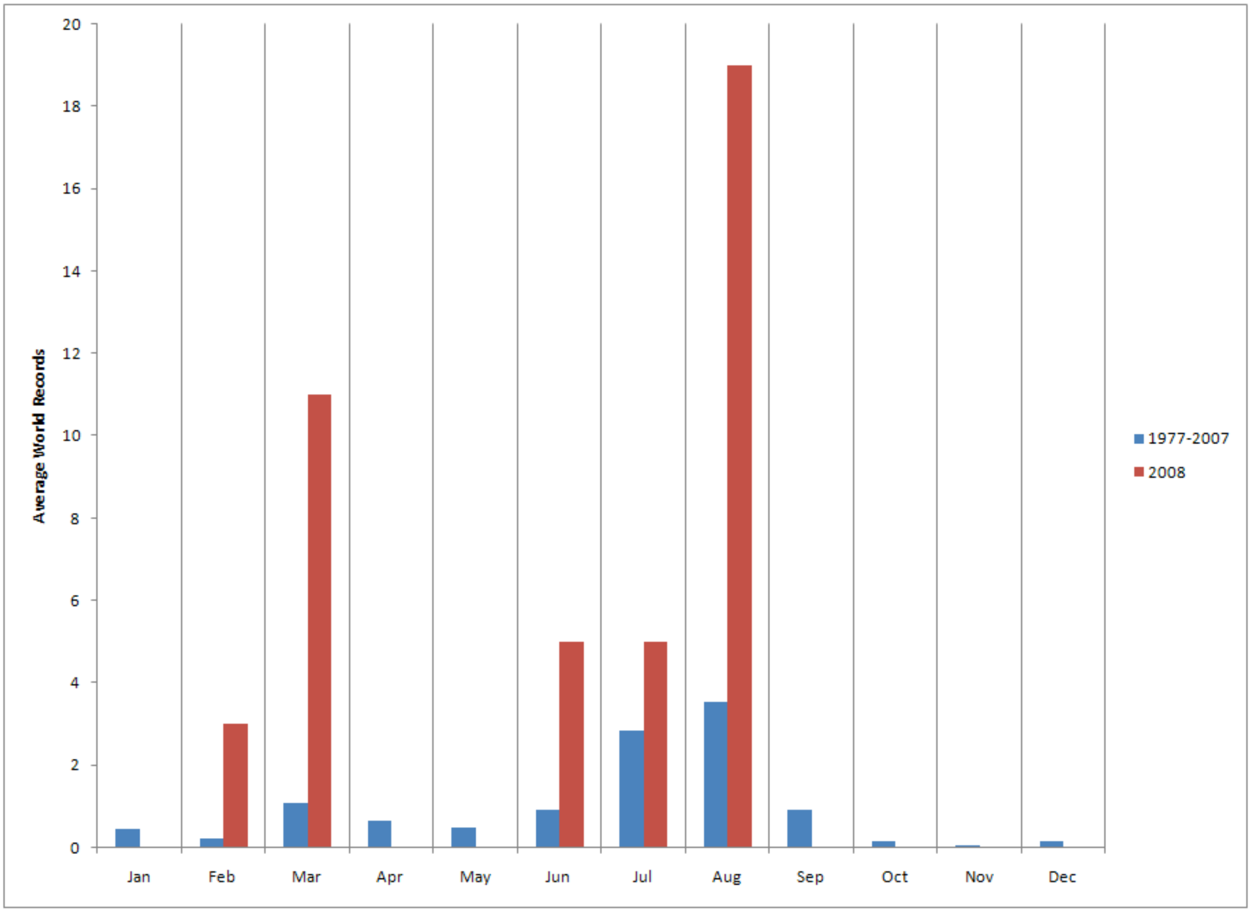


Figure 10. The occurrence of world records achieved in any given month for thirty years prior to 2008 and the year of 2008.

Regardless of the year (1977-2007), there were few significant differences between months ($F_{11,312}$=10.80, P<.01). Tukey's post hoc analysis revealed that the months of July and August have seen a significantly greater number of World Records broken when compared to all other months (*p*<0.01)(July and August were not different from each other). This may be due to the fact that there are more national or international competitions held during these two months of the year, consistent with a mono-phasic training plan at this high level of competition.

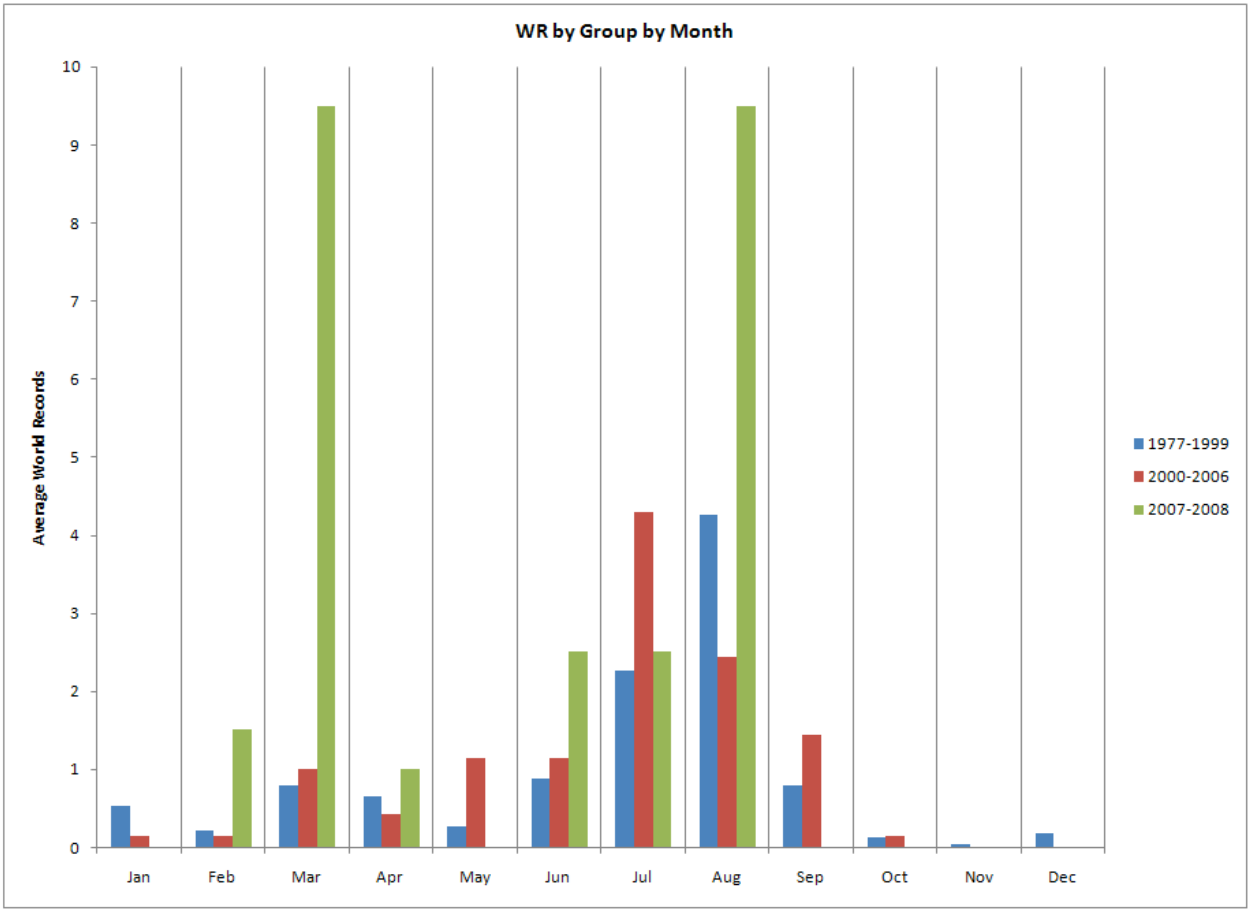


Figure 11 The occurrence of world records achieved in any given month of the year. Three time spans that are compared are; 1977 until 1999, 2000 until 2006; and 2007 until 2008 (present). The single statistical difference exists between 2007-2008 and the other time spans for February March. If all groups are pooled then records are set in July and August more often than in all other months.

Figure 10 and 11 suggest that from the perspective of “incident rates” a bias has recently been introduced into competitive swimming, in that, the number of record performances occurring recently (2007-2008) is much greater than what is predicted for all previous recent years. This recent rate even exceeds by nearly 100% the incident rates recorded during the previous peak months either July or August during which international championship events are commonly held. In the months of February and March there were 14 world records set in individual events. A one tailed t-test revealed significant differences between February and March of 2008 when compared to February and March of the prior 30 years (t_{59}=75.17, p<.01).

Performances at the 2008 Olympic Games were exceptional with multiple world, national, and Olympic records set. USA, Australia, Great Britain, Japan, China, etc all set National records at a pace unseen prior to 2008.

Put into context with the previous analysis, even during Olympic years, the rate at which World Records are broken - averages just over one a month. In March 2008, the number of world records set is nearly ten times that predicted from previous observations. Any explanation for this is speculative at this time. However, it would appear that introduction of the new high tech suits into high level competition corresponds to this dramatic increase. Continuation of this trend might suggest that the introduction has created a bias having a substanbtial impact upon swim performance. The prediction equations presented in the next section (Part II) will allow more definitive conclusions to be drawn about the existance of this bias.

At the 2008 Beijing Olympic Games the number of National, Olympic and World swim records set was almost unimaginable. In the individual events and the relays the records fell at an unprecidented rate. Whether or not this was due to the introduction of the new technology suits can not be proven per se. The only way to do so would be to invoke a rigid research design allowing for randomization and suitable control.

Part II The 2008 Japan Experiment

In preparation for the 2008 Games, the Japanese swimmers unintentionally conducted an experiment by wearing the new suits during high-level competition in the same pool Japan used earlier in the year (April, 2008) to hold their Olympic Trials. Because the Japanese swimming association was under contract with a different manufacturer the swimmers at their trials were not allowed to wear Speedo's LZR suit at the Japan Olympic trials. However, in the recent June meet, as a test, the swimmers were allowed to wear the new suit LZR from Speedo. When statistical analyses were performed, the swimmers (who did not wear the new suit at the first meet but did so at the second meet) were shown to swim faster in the second meet then at their trials (Figure 12). On average, swimmers swam 1.06% faster at the Japan Open when compared to Trials. Interestingly, the improvement was partially dependent on the distance of the event (Figure 13). Kitajima, arguably Japan's current best swimmer, improved his time in the 200 m breastroke by 1.5 seconds (setting a new world record) in the Japan Open over what he swam in the April Trials. While we cannot conclusively state that the improvements were due to the suits, it is further circumstantial evidence of an important effect. It might be reasonable to suggest that the swimmers should have swum faster at the Japan Olympic Trials than at the Open due to the need to be in top form to qualify for the Japanese National Team.

An additional observation here is that the sprint events (100 meters or less) were shown to be affected to a greater extent than were the distance events (200 meters or more).

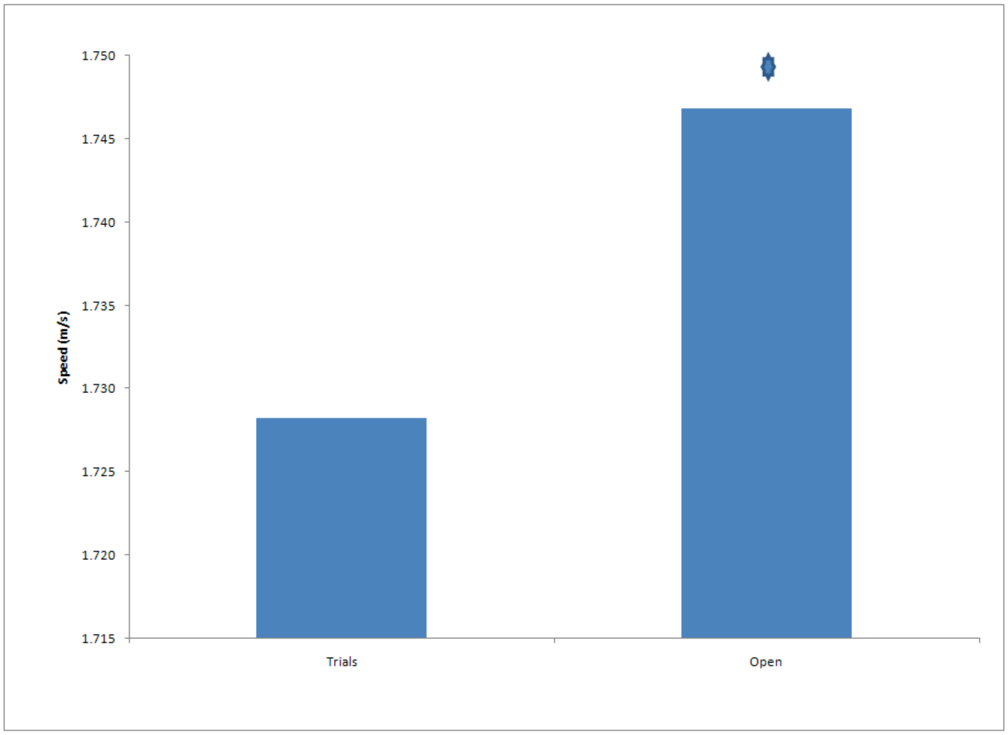


Figure 12. A comparison of the average speed of competitors at the Japanese Olympic Trials and the Japan Open. Swimmers were significantly faster at the Japan open when compared to the Trials.

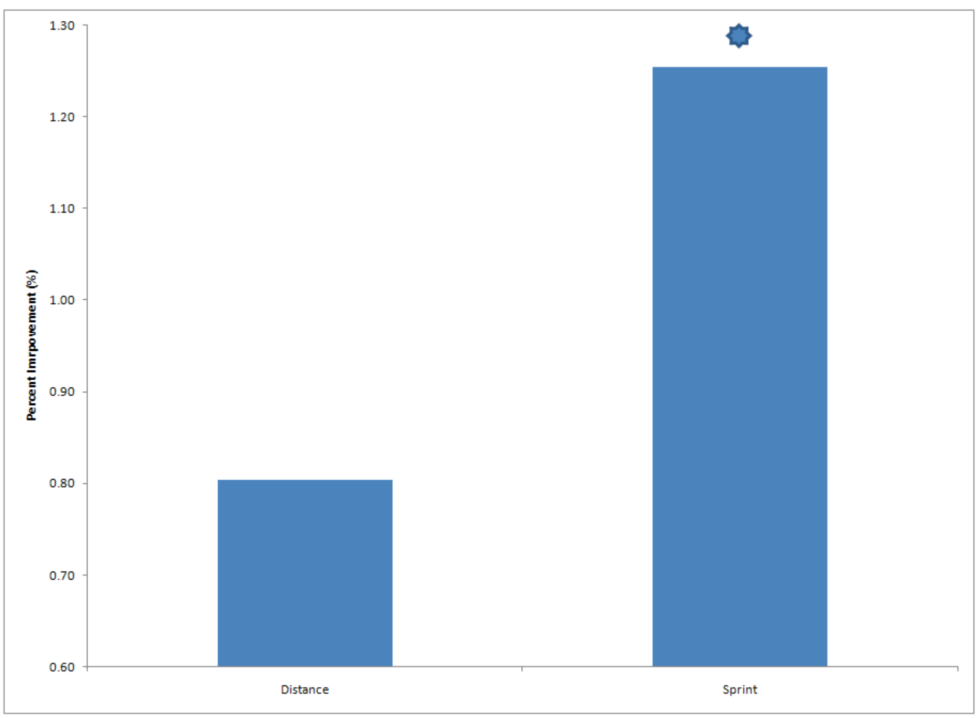


Figure 13. Percent improvement from Japanese Trials to the Japan Open for sprint (≤100M) and distance (≥200M) events. Sprinters improved significantly more than distance swimmers.

Part III. Descriptive and predictive modeling of Olympic trials and Olympic swim performance.

To extend the analysis of trends in swim performance further, our next step was to analyze the performances of the competitors at specific competitions and within specific events. Using the top eight performances in each event at recent Olympic Games or the USA Olympic Trials from 1972 through 2004, an "expected" or "forecasted time" can be calculated. As noted earlier, the progression in performance is such that improvements tend to get smaller from year to year and thus the line describing them is not linear, but rather one whose slope decreases as time progresses. The objective of this part of the study was to calculate predictions for the mean swim time of the top eight swimmers in each event at the 2008 Olympic Games based upon performances at the Olympics from 1972 through 2004, and to test the accuracy of previous predictions for the 1988, 1992, 1996, 2000 and 2004 Olympics. If it is assumed that this prediction curve is a smooth progression, then any significant deviations from it would suggest compelling events or cataclysmic changes have occurred within the sport. It is hypothesized that the accuracy of the predictions may fail as a function of unusual events in the world of swimming, such as boycotts, drug use, or perhaps swimsuit technology.

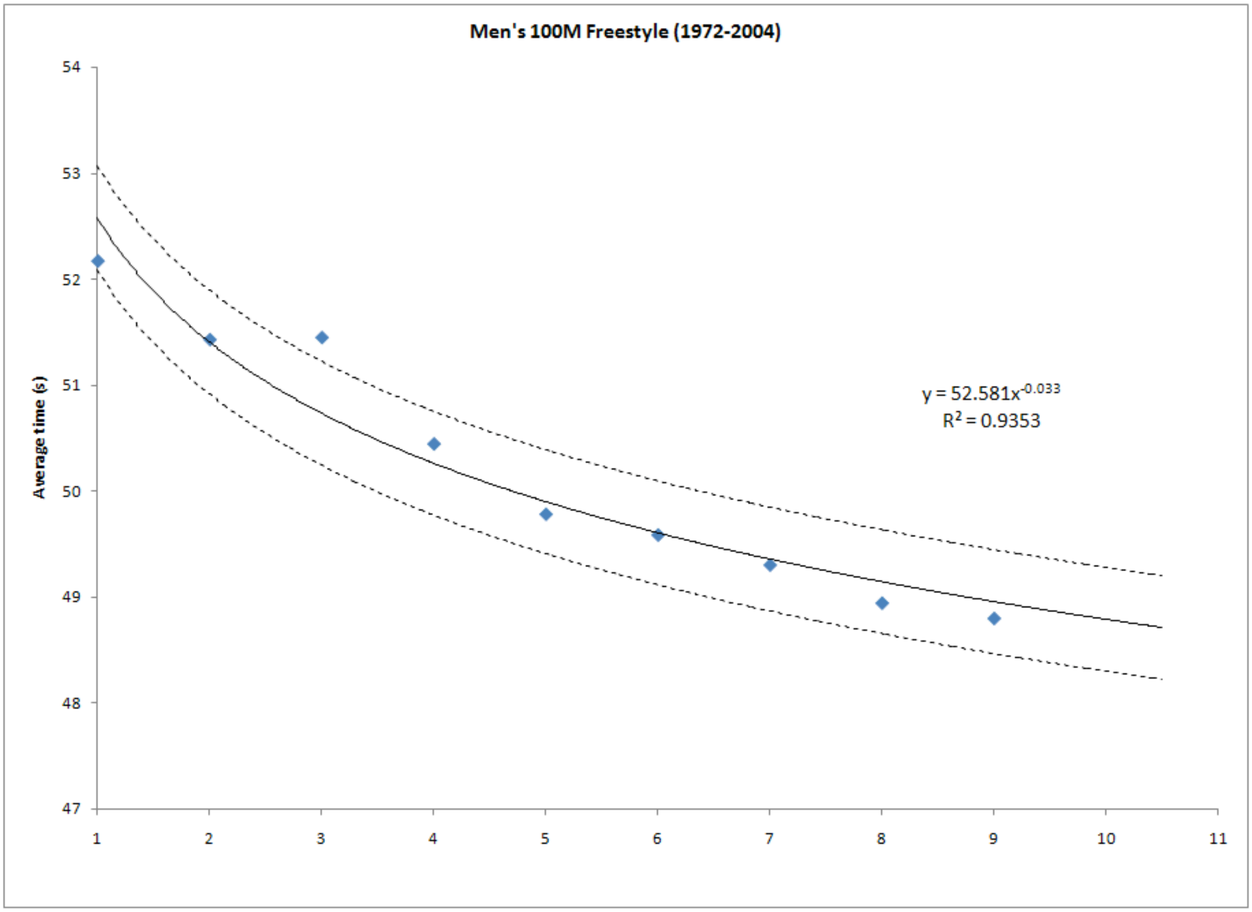


Figure 14. The average of the top 8 performances for the men's Olympic 100M Freestyle plotted against time (1972-2004). The x axis represents Olympiads being with 1972 (1 on the x axis) and continuing until 2004 (9 on the x axis). Note that the only Olympics during which swimmers did not perform as expected occurred in 1980 as a result of the "Olympic Boycott."

Methods

The top eight times from the finals of Olympic swimming events from 1972 through 2004 were analyzed for mean and standard deviation. A best-fit power curve of the form time = a*year^b was calculated across all years for each event, where a and b were coefficients and year was the code for the year of the Olympics (1 = 1972, 2 = 1976, ..., 9 = 2004). Using year = 10 to indicate 2008, the power equations were used to predict the mean of the finalists for each event of the 2008 Olympics. The percent difference between the predicted time and the actual time (absolute value) was calculated for each year and averaged within each event. This number was used to estimate the standard deviation of the predicted time for each event using the formula 1.25*(mean percent difference)*(predicted value)/100.

This standard deviation was used to establish the 95% confidence interval for that event (predicted time ± 2 standard deviations). The mean time of the finalists of the 2008 Olympics were compared to this 95% confidence interval. Actual times that fall outside the interval were significantly faster or slower than predicted.

To test this method, the same calculations were performed to establish power curves that fit the data from 1972 through 2000 only. The actual times from the 2004 Olympics were then compared to the 95% confidence interval as calculated from these curves to determine which events were faster, slower, or within the predicted range. A paired-samples t-test was used to determine the significance of the difference between the predicted and actual times for the 2004 Olympic men's and women's events. This process was repeated for each Olympic Games dating back to 1988.

To exam each Olympic year as a whole, a count was made of the number of events for which the actual time was above or below the corresponding prediction curve. This table of event counts was tested to determine whether or not a particular year was faster or slower, in general, than the prediction curve.

Results

The 2008 Olympic men's swimming events were fast by our estimation. Nine out of the 13 individual events recorded mean times for the eight finalists that were more than two standard deviations from the predicted outcome values. based on previous performances at the Olympics dating back into the 1960s. In several events the mean performances were in excess of 5 standard deviations faster than the projected mean. To put this in context, in the last Olympic Games, 2004 in Athens, the swimmers swam within our predicted range in all events. And, keep in mind, twenty-one world records were set in Beijing as compared to nearly one fifth that many in Athens. No men's events were slower in 2008 when compared to 2004. The least different event was the 1500 m freestyle.

In the women's events seven, a little more than half, were two standard deviations or more beyond our predicted values. Nearly all events were faster than in 2004 when compared to 2008 which was not true when the 2004 Games were compared with 2000 in Sydney. The single exception for the women is the 100 breaststroke as times were nearly identical to those recorded in 2004, being only a few hundredths of a second different.

The results of the swimming competition are, in general, exceptionally fast and do not fit the expectations of our mathematical modeling. It would appear that one or more bias has been introduced into the swim competition that did not play a role in determining the performances of the athletes until now. We would conclude that this bias has had a dominant role in enhancing performance in a manner inconsistent with the natural progression of swim performance that has been observed over the last half century.

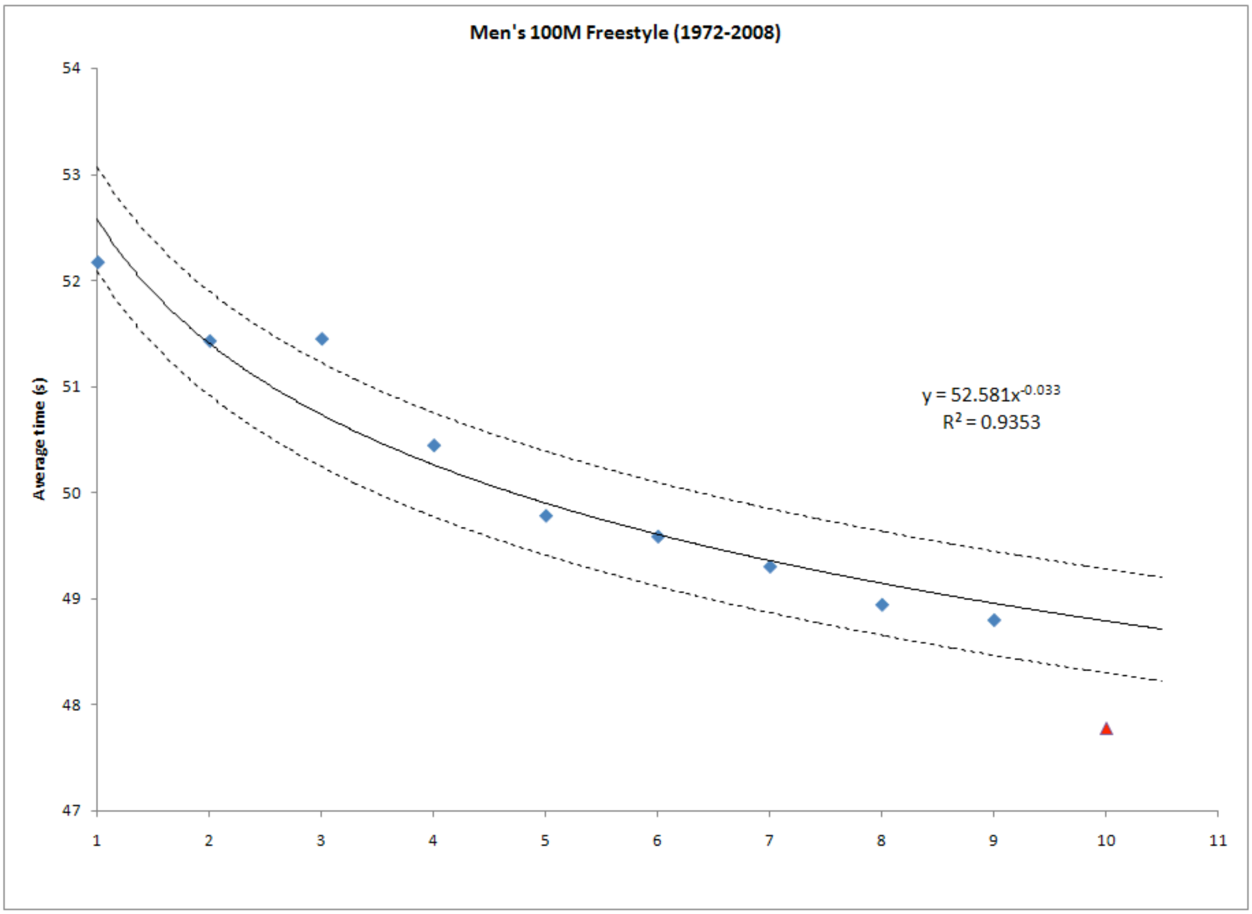


Figure 15. The average of the top 8 performances for the men's Olympic 100M Freestyle plotted against time (1972-2004). The x axis represents Olympiads being with 1972 (1 on the x axis) and continuing until 2008 (10 on the x axis). Note that the only Olympic Games in which the finalists swam faster than the prediction model occurred in 2008.

100 m freestyle

To further demonstrate the unusual nature of the 2008 Olympic Games (when viewed in context with earlier Olympics) we briefly consider here the men's 100 freestyle results. The 2008 Beijing Olympic

Games' average time for the eight finalists for the men's 100 freestyle was 47.77 seconds. This average time was nearly 4 standard deviations faster than our predicted time of 48.79 seconds and judged by us to be 'much faster' than expected. When compared to the performances at the previous 2004 Athens Olympic Games, the swimmers at the 2008 Games were, on average, 1.03 seconds faster (2.11%). Three of the four medalists (there existed a tie for the bronze medal) had previously swum within our confidence interval with the only exception being Cesar Cielo. (Gold: Alain Bernard, FRA, 47.21 sec, Silver: Eamon Sullivan, AUS, 47.32 sec, Bronze: Jason Lezak, USA; Cesar Cielo, BRA, 47.67sec). By comparison, the time improvement in swim performance in this event for the eight finalists between the 2000 and 2004 Games was 0.14 sec or 0.30%.

To further the point, we have compiled for comparison purposes the top twenty-five fastest times in the men's 100 meter freestyle prior to and after February 2008 (the introduction of the newest technology suits). Only one swimmer's time prior to 2008 remains in the top twenty-five after February 2008 and perhaps significantly, it is the twenty-fifth fastest time now while it was the all time fastest time previously. In less than six months twenty-four of the top twenty five times have been recorded.

Rank	Time	Name	Swim meet	Date
1	47.84	Van Den Hoogenband, Pieter	2000 Olympic Games	8/1/00
2	47.91	Nystrand, Stefan	2007 Paris Open	8/2/07
3	48.12	Magnini, Filippo	2005 World Championships	7/24/05
4	48.17	Van Den Hoogenband, Pieter	2004 Olympic Games	8/14/04
4	48.17	Schoeman, Roland	2004 Olympic Games	8/14/04
4	48.17	Lezak, Jason	2004 USA Olympic Trials	7/7/04
8	48.18	Klim, Michael	2000 Olympic Games Relay Leadoff	8/1/00
9	48.23	Schoeman, Roland	2004 Olympic Games	8/14/04
10	48.28	Schoeman, Roland	2005 World Championships	7/24/05
11	48.33	Ervin, Anthony	2001 World Championships	7/22/01
12	48.34	Neethling, Ryk	2005 World Championships	7/24/05
13	48.38	Schoeman, Roland	2005 ConocoPhillips Nationals	8/3/05
13	48.38	Schoeman, Roland	2004 Olympic Games	8/14/04
15	48.39	Schoeman, Roland	2004 Olympic Games	8/14/04
15	48.39	Van Den Hoogenband, Pieter	2003 World Champs	7/20/03
17	48.41	Lezak, Jason	2004 USA Olympic Trials	7/7/04
18	48.42	Phelps, Michael	2007 World Championships	3/25/07
18	48.42	Popov, Alexander	2003 World Champs	7/20/03
18	48.42	Biondi, Matt	1988 USA Olympic Trials	8/10/88
21	48.43	Hayden, Brent	2007 World Championships	3/25/07

21	48.43	Magnini, Filippo	2007 World Championships	3/25/07
23	48.45	Schoeman, Roland	2005 World Championships	7/24/05
24	48.47	Sullivan, Eamon	2007 World Championships	3/25/07
25	48.49	Gilot, Fabien	2007 French Open Champs	6/24/07

Table 2. The fastest times ever recorded in the men's 100 meter freestyle. The oldest performance occurred in 1988 while the six of the top twenty five occurred in the last year considered here; 2007.

Rank	Time	Name	Swim meet	Date
1	47.05	Sullivan, Eamon	Beijing Olympic Games	8/9/08
2	47.20	Bernard, Alain	Beijing Olympic Games	8/9/08
3	47.21	Bernard, Alain	Beijing Olympic Games	8/9/08
4	47.24	Sullivan, Eamon	Beijing Olympic Games	8/9/08
6	47.32	Sullivan, Eamon	Beijing Olympic Games	8/9/08
7	47.50	Bernard, Alain	2008 European Champs	3/18/08
8	47.51	Phelps, Michael	Beijing Olympic Games	8/9/08
10	47.52	Sullivan, Eamon	2008 AUS Olympic Trials	3/22/08
11	47.56	Hayden, Brent	Beijing Olympic Games	8/9/08
13	47.58	Lezak, Jason	2008 USA Olympic Trials	6/29/08
14	47.60	Bernard, Alain	2008 European Champs	3/18/08
15	47.67	Lezak, Jason	Beijing Olympic Games	8/9/08
15	47.67	Cielo, Cesar	Beijing Olympic Games	8/9/08
17	47.68	Van Den Hoogenband, Pieter	Beijing Olympic Games	8/9/08
18	47.75	Van Den Hoogenband, Pieter	Beijing Olympic Games	8/9/08
19	47.76	Leveaux, Amaury	Beijing Olympic Games	8/9/08
21	47.78	Weber-Gale, Garrett	2008 USA Olympic Trials	6/29/08
22	47.80	Sullivan, Eamon	Beijing Olympic Games	8/9/08
23	47.82	Bernard, Alain	2008 FRA Olympic Trials	4/20/08
24	47.83	Nystrand, Stefan	Beijing Olympic Games	8/9/08
25	47.84	Van Den Hoogenband, Pieter	2000 Olympic Games	8/1/00

Table 3. The current fastest 100 meter times (LONG COURSE) for men. All but one performance occurred before 2008, that of Peter Van Den Hoogenband in 2000. More than 50% of the top twenty five times were recorded at the Beijing Olympic Games in August of 2008.

Pooled comparisons events

When all events are “pooled” the 2008 Games can be compared with other recent Olympics. Figure 16 suggests again that the 2008 Games were much faster than previous Games with the average event offset being faster than statistical models by more than 3 standard deviations. From 1988 until the present only one Games was significantly different from the modeling and that occurred in 1996. In that case, however, the swimmers were slower than predicted, not faster.

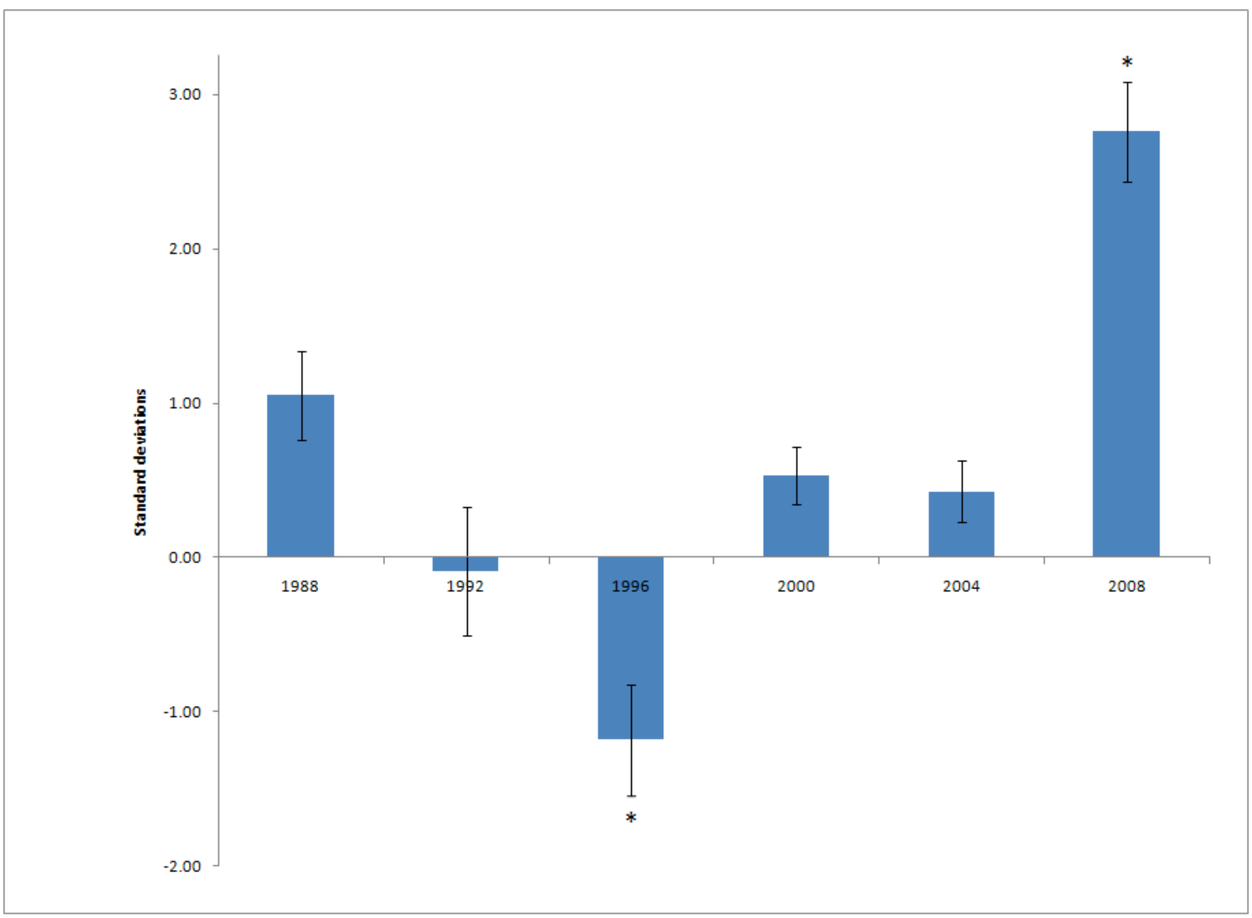


Figure 16. Values represent average standard deviations the actual mean was from the predicted mean. A positive value denotes the actual mean was faster than the predicted mean. * denotes significant difference compared to all other groups. However, 2008 was the only year when our predictions were outside of ± 2 standard deviations. The Games in 1996 were, by comparison, slightly more than one standard deviation slower than the model would predict. Table 4 presents the data in a different manner. The number of events for men and women are shown relative to their agreement or disagreement with our mathematical model.

Table 2. Percent of total events successfully predicted for each Olympic Games (1988-2008) for male, female, and combined.

	Male %	Female %	Tot %
1988	63.64	90.91	77.27
1992	75.00	58.33	66.67
1996	91.67	66.67	79.17
2000	92.31	100.00	96.15
2004	84.62	100.00	92.31
2008	23.08	46.15	34.62

Table 4. Predictive success of the modeling process used in the current analysis. As time goes on the model should become more robust as additional recent data is added to the model. That did not occur in 2008.

Predicted Top 8 Times for the 2000 Olympic Swimming Events						
	Predicted				Actual	
Men's Events	Time	± S.D.	95% Confidence Interval		Time	
50 Free	22.28	0.11	22.06	22.51	22.19	
100 Free	49.28	0.29	48.71	49.86	48.95	
200 Free	107.58	0.75	106.07	109.08	107.43	
400 Free	227.10	1.50	224.10	230.09	226.21	
1500 Free	899.22	9.46	880.30	918.14	901.67	
100 Back	55.03	0.47	54.10	55.96	54.85	
200 Back	119.79	0.78	118.23	121.35	118.43	
100 Breast	61.47	0.32	60.82	62.11	61.25	
200 Breast	132.86	0.93	131.00	134.73	132.85	
100 Fly	53.16	0.29	52.58	53.73	52.53	faster
200 Fly	117.54	0.62	116.30	118.78	116.69	
200 IM	121.26	0.31	120.64	121.87	121.13	
400 IM	255.79	0.63	254.53	257.05	256.74	
	Predicted				Actual	
Women's Events	Time	± S.D.	95% Confidence Interval		Time	
50 Free	25.14	0.10	24.95	25.34	25.01	
100 Free	54.98	0.35	54.27	55.68	54.76	
200 Free	118.64	0.67	117.30	119.99	118.92	
400 Free	247.81	1.97	243.87	251.75	249.46	
800 Free	508.45	3.81	500.84	516.06	507.82	
100 Back	61.52	0.39	60.74	62.29	61.12	
200 Back	130.60	1.08	128.44	132.76	131.71	
100 Breast	68.26	0.35	67.57	68.96	68.17	
200 Breast	146.36	0.94	144.48	148.24	145.64	
100 Fly	59.41	0.49	58.43	60.39	58.48	
200 Fly	129.43	0.65	128.13	130.73	128.19	
200 IM	134.01	0.55	132.91	135.12	133.51	
400 IM	278.41	3.05	272.31	284.52	280.84	

Table 5. Using prediction modeling and based on previous performances during Olympic competition the event outcomes at the 2000 games were swum as predicted with a single exception, the men's 100 fly. All of the women's events finished within the expected range.

Predicted Top 8 Times for the 2004 Olympic Swimming Events						
	Predicted				Actual	
Men's Events	Time	± S.D.	95% Confidence Interval		Time	
50 Free	22.10	0.10	21.91	22.29	22.11	
100 Free	49.00	0.27	48.46	49.54	48.80	
200 Free	107.13	0.67	105.80	108.47	106.49	
400 Free	225.90	1.39	223.13	228.67	225.92	
1500 Free	896.68	8.30	880.07	913.29	898.05	
100 Back	54.76	0.42	53.93	55.60	54.52	
200 Back	118.97	0.85	117.28	120.66	117.98	
100 Breast	61.14	0.31	60.53	61.75	61.15	
200 Breast	132.21	0.81	130.58	133.84	131.14	
100 Fly	52.77	0.33	52.12	53.43	51.98	faster
200 Fly	116.92	0.68	115.56	118.28	115.89	
200 IM	120.74	0.29	120.16	121.32	119.71	faster
400 IM	255.00	0.71	253.59	256.42	254.71	
	Predicted				Actual	
Women's Events	Time	± S.D.	95% Confidence Interval		Time	
50 Free	24.89	0.09	24.71	25.07	24.96	
100 Free	54.69	0.33	54.04	55.34	54.58	
200 Free	118.32	0.62	117.08	119.57	118.69	
400 Free	247.56	1.84	243.87	251.24	248.05	
800 Free	506.76	3.41	499.94	513.59	509.06	
100 Back	61.13	0.39	60.35	61.91	61.07	
200 Back	130.33	1.11	128.12	132.54	130.69	
100 Breast	67.81	0.31	67.18	68.44	67.39	
200 Breast	145.25	0.92	143.41	147.08	145.49	
100 Fly	58.89	0.52	57.86	59.92	58.54	
200 Fly	128.59	0.80	126.99	130.19	128.58	
200 IM	133.27	0.48	132.30	134.23	133.24	
400 IM	278.46	2.65	273.15	283.76	281.00	

Table 6. Using prediction modeling and based on previous performances during Olympic competition the event outcomes at the 2004 games were as predicted with two exceptions; the men's 100 fly and the men's 200 IM.   All of the women's events finished within the expected range.

Predicted Top 8 Times for the 2008 Olympic Swimming Events							
	Predicted				Actual		
Men's Events	Time	± S.D.	95% Confidence Interval		Time		
50 Free	22.00	0.08	21.84	22.16	21.57		faster
100 Free	48.79	0.30	48.19	49.39	47.77		faster
200 Free	106.61	0.65	105.31	107.90	105.81		
400 Free	225.09	1.21	222.66	227.51	223.72		
1500 Free	894.18	8.82	876.53	911.83	888.61		
100 Back	54.50	0.40	53.70	55.31	53.28		faster
200 Back	118.31	0.81	116.70	119.92	115.54		faster
100 Breast	60.91	0.29	60.34	61.48	59.64		faster
200 Breast	131.34	0.92	129.49	133.19	129.44		faster
100 Fly	52.38	0.35	51.68	53.08	51.23		faster
200 Fly	116.33	0.64	115.05	117.60	113.86		faster
200 IM	120.02	0.39	119.24	120.81	117.88		faster
400 IM	253.99	0.63	252.72	255.25	250.54		faster
	Predicted				Actual		
Women's Events	Time	± S.D.	95% Confidence Interval		Time		
50 Free	24.79	0.09	24.62	24.97	24.36		faster
100 Free	54.46	0.30	53.86	55.05	53.80		faster
200 Free	118.08	0.56	116.96	119.19	116.35		faster
400 Free	247.02	1.78	243.45	250.59	244.90		
800 Free	505.93	3.58	498.77	513.08	504.42		
100 Back	60.87	0.35	60.16	61.58	59.53		faster
200 Back	129.91	0.98	127.95	131.87	127.77		faster
100 Breast	67.32	0.33	66.66	67.98	67.30		
200 Breast	144.51	0.84	142.83	146.20	143.30		
100 Fly	58.57	0.49	57.59	59.55	57.70		
200 Fly	128.15	0.69	126.77	129.54	126.58		faster
200 IM	132.74	0.42	131.91	133.57	130.86		faster
400 IM	277.97	2.72	272.53	283.41	275.16		

Table 7. Using prediction modeling and based on previous performances during Olympic competition the event outcomes at the 2008 games were judged to be ' not as predicted' with three exceptions for the men; 200 m free, 400 m free and the 1500 m free. All other events were faster then predicted. Eight of the women's events finished faster than the predicted range. No events were slower than predicted.

Finally, the outcome of all the events from the 2000, 2004, and 2008 Olympic Games are illustrated in Tables 5, 6 and 7. Essentially, the games in 2000 and 2004 resulted in performances accurately predicted using the performances swum in previous years to generate the newest model. Our conclusion is that the introduction of the first and second generation of 'hi tech' swim suits had no measurable effect upon swim performance. Only three events (out of a possible 52) were judged to be faster than our model predicted seems to validate our approach. However, in 2008, the modeling failed with more than half (17 of 26 events) being faster than predicted using identical methods as before.

If the question is asked: How long should it have been before the times generated at the recent games would normally have been observed (assuming the actual unbiased progression is valid) the model developed prior to 2008 allows us to calculate an answer.

Men

Event	**2008 Top 8**	**STD**	**Upper CI**	**Olympiad#**	**Year**
50Fr	21.57	0.08	21.73	13	**2020**
100Fr	47.77	0.25	48.27	14	**2023**
200Fr	105.81	0.64	107.10	9	2002
400Fr	223.72	1.23	226.18	9	2002
1500Fr	888.61	7.36	903.33	7	1996
100Bk	53.28	0.38	54.04	13	**2019**
200Bk	115.54	0.86	117.27	13	**2020**
100Br	59.64	0.27	60.18	14	**2024**
200 Br	129.44	0.89	131.23	10	2008
100Fly	51.23	0.38	51.99	12	**2017**
200Fly	113.86	0.77	115.39	13	**2021**
200IM	117.88	0.47	118.83	13	**2021**
400IM	250.54	0.66	251.85	13	**2018**

Women

Event	**2008 Top 8**	**STD**	**Upper CI**	**Olympiad#**	**Year**
50Fr	24.36	0.09	24.53	12	**2016**
100Fr	53.80	0.30	54.40	10	2009
200Fr	116.35	0.58	117.51	12	**2015**
400Fr	244.90	1.65	248.20	8	2001
800Fr	504.42	3.29	511.00	7	1995
100Bk	59.53	0.35	60.23	13	**2021**
200Bk	127.77	1.02	129.80	10	2008
100Br	67.30	0.33	67.95	8	2001
200 Br	143.30	0.84	144.98	9	2005
100Fly	57.70	0.48	58.66	10	2006
200Fly	126.58	0.71	128.00	10	2009
200IM	130.86	0.42	131.69	12	**2017**
400IM	275.16	2.47	280.10	8	2000

Figure 8. Analysis of the results of the 2008 Olympic Games and when the mean times for the top eigth finalists "should" have been observed had there been no bias introduce. For the men, for those events that were 'accelerated' were done so, on average, by 12 years or 2020. For the women, the accelerated events were done so by about 9 years.

Conclusion:

Given the evidence provided here we conclude that there has been a substantial bias introduced into the swim community early in 2008. This bias has effected the performances of the men, more so than the women. There is little to no evidence to suggest this bias existed before 2008 as our predictive modeling was successful in describing swim performance at the highest levels until now. Added to this, is the unnatural rate of record progression at the National and International level. We therefore conclude that a significant and 'unnatural' bias has been introduced into the sport. Personal communication with coaches and athletes at this level has not provided any evidence of innovation other than perhaps the introduction of new technology suits into the sport. The additional thought offered was that if it was coaching, or coaching technique then the bias should have been as evident in the women as in the men. This leads to the hypothesis that the new suits do aid performance, particularly so in the men, and that in the future, to be competitive at this level will require having one to wear. It would seem that this is contrary to the rules that govern the sport of swimming in that prior to now swimmers were not permitted to wear any equipment that would alter their buoyancy or aid their performance. How the suits act to alter performance is currently unknown, as much of this information is considered proprietary by the firms providing them. However, it is possible to suppose mechanism given the greater effect in men as compared to women and greater affect in short events as compared to longer events. In view of this, further research into this aspect is recommended if our sport is to proceed with equal opportunity and competitive "fairness" for all. Finally, if in fact the suits can be shown to directly alter swim performance, it will be difficult to assess and reconcile current performances with those in our sport's history. Future analyses of swim performance will likely show that a slope in the progression of performance similar to what existed prior to 2008 will again exist for future events. An offset will be observable likely caused by the newly introduced bias. As has been previously predicted, if all the competitors wear the suits (assuming the bias is caused by the suits) then it will no longer be an advantage other than permitting all swimmers to break the previously existent swim records. The progression in times, however, will again slow as swimmers continue to approach the inescapable limits of *equipment aided human* performance.