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**How Fast can Usain Bolt Run?**

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I am going to run through quite a number of different sports with focus on the 2012 London Olympics.

I have picked on one particular topic for this lecture, a rather fashionable one, with Mr Bolt. That at least has the advantage that everyone here will have heard of him, although, when I first looked for some pictures, I discovered that there is a rather successful, and in some circles well-known, racehorse who is called Usain Colt, and you will tend to come upon him quite often in your Google search.

I am just going to focus on Bolt’s 100 metre running today. There is a lot to be said about 200 metre running, but there isn’t time to talk about that as well today.

I have a picture which shows the evolution of the men’s 100 metre sprint record, back from about the time of the 1908 and 1896 Olympic Games, the sort of times when I could have won it, and moving forwards. The change in the size of their bars reflects the accuracy to which timing took place. You can see full electronic timing results in very small error bars – you are suddenly timing to a hundredth of a second rather than just to a tenth. In 1936, Harold Abrahams would have been running about 10.6 seconds for 100m, and Bolt territory it is just below 9.6, although there was a long period when there was not really very much change, when the record hung around 10 seconds, and then around 9.9.

But the progression of this record is really quite slow, if you compare with what happens in other sports, and the most interesting case is to compare, say, swimming with running.

If we pick not an event that goes over the same distance but compare events that are for about the same time, then we would be comparing 100m swimming with 400m running. For the 100m swim back in 1968, Mike Wenden won the Olympic Games in Mexico City, in 52.2 seconds. You would be hard pushed to qualify for the women’s final now with that time. It would not even make the American Olympic team. Nowadays it is 46.91 with a little bit of help from hydrophobic swimming suits, but even without them it is 47 seconds. Since 1968, over a 43-year period, there has been a huge 6.5 second or so improvement in performance.

Look at what happens in 400m running: 43.8 seconds to win in 1968, a very, very good record. A few years ago now, Michael Johnson won in 43.18 – there is almost nobody running even this today, so there is almost no progress, maybe about 0.6 of a second in running for the same period of time.

We will see, in later lectures in this series, some of the reasons why that has happened in swimming. Swimming is the most technical probably of all Olympic events, where research and understanding of hydrodynamics and motion and resistance and technique produces enormous improvements in performance. With running it is not so easy. The basic motion is much simpler. You are moving through air rather than through a liquid.

The progress of both the men’s and women’s world records has been pretty relentless, and it shows no sign of stopping. Every time there is a major championship in swimming, there is a world record in almost every event. There are no longstanding records in the shorter events.

If we look at a whole span of events, there is a rather interesting systematic relationship, which extends even beyond the schedule of events that you would see in the Olympic Games. If you take any running event and you work out the average speed of the best performer, that is just dividing the distance by the time, so it would be 100m divided by 9.58, and you do that for every event, all the way up to the marathon, then what you have is the average speed at which the athlete is performing that distance. And if you plot that against the distance, in metres, it is a very, very good straight line on a chart. And what that means is that the average speed falls off like a power of the distance, and that power is minus 0.11, to very good accuracy, and it is pretty much exactly the same for the women, so the two lines are parallel. There is a very good systematic relationship between human running performance and distance. And you can keep this going, to ultra-marathon distances and beyond. You can do it for other sports too. You will get a different curve, but, pretty much, you will get a straight log-log relationship.

Something I noticed that sports scientists had never seemed to take much interest in are the Paralympic performances and particularly wheelchair events. One of the unique things about the 2012 Games is that they are the first ones where the Paralympics and the ordinary Olympics are not separate events. They are regarded as one and the same. They are part of a single Olympics. Sports scientists have really spent very little time studying what goes on in Paralympic events, with the exception of the arguments about Mr Pistorius.

I have the same plot for wheelchair events. If you work out the average speed against distance, you soon recognise there is something very strange about wheelchair events: there is essentially no fall-off in the average speed against distance. This is something you might suspect if you just look at the famous names in this sport. You would find people like David Weir, for example. They have gold medals in the 100m and the 800m and they are winning the London Marathon. This is inconceivable in regular athletics events.

There is an enormous range of competitions in which the top athletes in wheelchairs take part. The average speed in the 10,000 metre world record is lower than the average speed in the marathon world record. No doubt, going around lots of bends on the track is something that is rather awkward, whereas, in the marathon, there are more marathons to compete in, it is more competitive, but it is a better terrain for wheelchair athletics.

There is also a strange lack of standardisation in wheelchair weights. There is lots of standardisation in, for example, where the centre of gravity must be, and the height, and rules about things hanging off the sides, but none about their weight, which is most peculiar because, on the track, rolling friction is a key form of resistance. So, if you look at those formulae again, you see the curves are almost flat. There is virtually no dependence, no significant fall-off, in average speed with distance.

Now we will get get back to Mr Bolt. What we are interested in is looking more carefully at are his past performances and what he might do in the future, how he might run faster, without actually having any improvement whatsoever physiologically in his running performance. How could that be?

At the Beijing Olympic Games, he ran a time of 9.68 for 100m and, in 2010, at the World Championships, he improved this by a whole tenth of a second, to 9.58. There is an “instant” time on the electronic clock, which gets rounded down to 9.68.

First of all, when you look at a performance like that, you look at the times in athletics events, and you have to divide them into two pieces. They are composed of what you might call a “run” time, the time it actually takes you to run 100m, and a “reaction” time, the time that it takes you to respond to the gun.

I was alarmed to see recently that *New Scientist* had an article by a group of Stanford biologists analysing what would be the fastest speed that Bolt could run, who, having missed this point, ended up making future predictions about what Bolt’s ultimate speed of running would be that were actually slower than the speed at which he runs at the moment, which is rather unfortunate.

When you look at high-level athletics, what you have to realise is that the false start rule is that if you respond in any measurable way to the electronic triggering of the gun, in less than a tenth of a second, or 100 milliseconds, then you are defined to have false-started, whether you have left the blocks or not. So if you just exert some toe pressure on your starting block, that will register as a false-start movement. Nowadays, you don’t have any grace: you don’t have a second chance. As Bolt himself discovered, you will be disqualified for making that false start, unless it can be shown that you were responding maybe to somebody screaming in the crowd or clicking their camera, in which case it would be a faulty start. So, in Daegu last summer, an event which attracted much publicity, Bolt did not even try to react quicker than 0.10, he reacted 0.104 before the gun was triggered, so this was a failure of concentration.

These electronic triggerings of starts are important. When you and I were at school, maybe people started races by having a gentleman in an orange blazer hold a gun in the air and fire it. Nowadays, he would be arrested by anti-terrorist police just before he fired the gun, so starters are not allowed to own pistols anymore, let alone fire them! But, as you probably realise, if we have our runners along the start line, and a starter with his gun, say five metres away on the in-field, then the person in the outside lane is probably about 15m away from the starter, and you have to worry about the speed of sound. Okay, speed of sound is about 340m per second, and so the inside lane, here, is going to hear that sound of the gun rather sooner than the person on the outside, and the benefit that being close to the starter gives is, obviously, 15 minus 5, divided by the speed of sound. Which is about 0.029, 0.03 of a second, and that is easily enough to be the difference between winning and coming fourth, so you cannot start high level international sprint races by firing guns from a particular point on the in-field. So what you do is that you have microphones, in effect, and there is an instantaneous transmission of the sound of the gun to each starting point at the same moment.

If you lived in America long ago, you might have had the experience of seeing a 200m race run on a straight track. There used to be one of these at Oxford, when I was a graduate student there, at Ifley Road. It was changed in 1975. But, in the USA, it was quite common to have 200m straightway tracks, as they were called, and there were always surprisingly fast times recorded on 200m straightways. Of course, you had the possibility that you had wind assistance behind you all the time, but the other reason was that timekeeping really was a very dodgy business. The timekeepers are, at the finish, 200m away from where the starter fires his gun, so there is a sound travel time of 1.7 seconds between the start and the timekeepers at the finish, therefore there was huge latitude for uncertainty and error as a result of that. So, before you have electronic timings, this is a very awkward event to try and run.

What used to happen, in those days before electronic timing and before people started defining electronically what a false start was, was that you would have athletes who were what I would call professional anticipators. The most famous anticipator was the 1960 Olympic champion, Armin Hary, from Germany, and he perfected the art of starting on the sound of the gun. He did not wait to hear it – he would simply, I suspect, listen to the starter starting many earlier events in the programme, and he would eventually work out what was the delay that was being used by the starter. Most starters have a little system – they say, “Get set,” 1001, bang. He will do that every time, so if you listen carefully to the starter, you can work out what his little delay is, and make sure that you also say to yourself “1001” and off you go. Hary perfected this. He equalled the world record, at the time, 10 seconds flat. When he was subjected to some electronic investigation, it was found that he was reacting, on occasions, apparently with reaction times of 0.04 of a second, which is physiologically impossible, by a large margin.

I have some statistics of reaction times of sprinters in major championships over a six year period, showing their final time and their reaction time. Remember, if you are below 0.10 you would be disqualified, so there are some people who are really very, very fast reactors, and you do not know if they are doing that systematically or if it is just rather lucky. There is a rather weak trend that fast reactors get fast final times overall, but it is a trend, nonetheless.

The interesting thing about Mr Bolt is that he is one of the slowest reactors of all top athletes; he has the slowest reaction time amongst major sprinters. For example, in the Berlin World Championships in 2010, he set a record of 9.58. If you look at the split of each athlete’s reaction time and then their running time, you will see that Bolt is up in the 1.46 reaction time. His rivals are all significantly faster, except for two. I would highlight two, Dwain Chambers and Burns. Burns actually runs significantly faster than Chambers, but because he reacts so slowly, he ends up finishing behind Chambers, although they have the same time.

In the Olympic final, two years before, Bolt is even worse. He reacts in 0.165 of a second, so he is the second slowest reactor in that final, showing that this is not a one-off. Every time, he is a very slow reactor to the gun.

If we look at physiological evidence of testing in laboratory and testing of athletes involved in big championships, there is another curious feature of sprinters’ reactions. If you examine all the athletes that took part in sprint events at the Beijing Olympics: the men, the women, the reaction time in milliseconds, the histograms, you can see where the means look like. It is about 0.168 of a second for the men, 0.191 for the women.

The difference between men and women is not new to this data. It has always been something of a mystery, ever since such data has been collected, 70 or more years ago. There has always been a systematic difference between the average reaction time of men and women. Long ago, there used to be theories put forward to try and explain this, for example, not so many women drove cars as men did – this does not apply now of course – but there is no very good or clear explanation as to why there is this difference. It might just be directly linked to muscular power and strength driving a response. But if you look at the statistics, the number of false starts that there were in Beijing, the number of people reacting to the gun faster than that 0.10 here, there were 25 by men and four by females, which is consistent with this type of difference. You see, if females have a slower reaction time, they are much less likely to false-start than men, and what this evidence implies is that there should be a different false-start rule for men as there is for women, by a few milliseconds. You heard it first here!

I have another chart of these reaction time data and the fraction of athletes who are reacting at a particular reaction time. 5% only are reacting within 0.12 of a second. Someone like Colin Jackson, who was probably the best consistent starter of all in modern athletics, never false-starts, so it is a real reaction response. But 50% are up about 0.145. You remember where Bolt was, he was 0.146, and then in the Olympics,he was 0.165, so he really is well down the statistical distribution. His performance in Daegu would not even fit on this chart because he reacted before the gun so he has a negative time.

My first improvement tip to Mr Bolt is to improve reaction time. If you can even get it down to 0.12, which, although uncommon, lots of top athletes can, then you lop three hundredths of your record – it will be down to 9.55. Go down to the margin, to 0.10, and you are down to 0.53.

The second thing we are going to look at is wind assistance. There is a picture here of a track that looks rather like one which I ran around rather a lot when I was young, and it has a sign that is telling you 2m per second. This is the maximum following wind that is allowed for a performance to be valid for record purposes. You can win the Olympic Games with a 10m per second following wind, and you can even set an Olympic record, but you cannot set a world record.

What are the ingredients that affect wind assistance and wind resistance, which is more noticeable, if you are running into the wind? One that is familiar, that you see particularly in cycling and in speed skating, is that people attempt to streamline their body profile to reduce the area that they are presenting to the wind in the direction in which they are moving.

For example, for a skydiver, which is an extreme situation, if you are coming down headfirst, then the body area that you are presenting in the direction of motion is really rather small. If you come down at an angle, you are presenting something bigger. If you are laid out with your arms outstretched, you are presenting almost your whole body area. If you move your legs out, you will present the maximum surface area and experience the most resistance. If you curve a bit, it will be reduced. So you can see how manipulating your body shape allows you to change the speed with which you would fall. I am not a skydiver, and Barrow’s first law is: if at first you don’t succeed, then skydiving isn’t the sport for you!

We will look at what the role of the air is when you sprint through it. Suppose that you are sprinting along, at some speed v, and you are presenting an area of your body in the direction in which you are moving, we will call this A. Then, what is the force that you feel as you move through that air?

If you run through air for a time, t, what is the mass of this cylinder, this tube of air, that you are sweeping out as you move? It is the density times the volume. The density of air we will call rho. What is the volume? It is the area, times the speed, times the time. So this is the mass of air that you are displacing as you move for a time, t, at speed, v, through air of density rho. The thing I have called A’, it is the area you are presenting, but it will have some other factor in there that will determine whether you are wearing some sort of lycra suit, so something that is more aerodynamic than wearing a duffle coat or a tracksuit or something like that. There is a little fudge factor here, which will be of order one, which will depend on details of how smooth your surface is. So the drag force from the still air is opposing your motion, therefore I gave it a minus sign. It is going to be that mass, times a measure of acceleration: Newton’s second law. Acceleration, roughly, is the speed divided by the time. So the drag force, if the air is still, is the density, little fudge factor, the area, times your speed squared.

But what if there is a wind blowing? If there is a wind behind you, it will be advantageous. If you are going into a wind, you will have to do more work: you will need more force to overcome it. If the wind is behind you, and its speed is w, it will be a positive wind. If it is a headwind that you are running into, it will be negative. And so, if you make the quantity w negative, this is positive, and you will need more force to overcome the wind. When you see athletic performances, you will see a sprint time, and it will have in brackets “plus 1.0”. It means there is a following wind of one metre per second. If it has “minus 1.0”, there is a headwind of minus a metre per second.

We can do a number of things with this formula. The first one is to think about people who run round whole laps, 400m, 800m, all the way up to 10,000m on the track, or even round the quad at Trinity College. Is it a swing and roundabouts problem? You would think that if you have the wind behind you in the home straight, you are going into it down the back straight, so doesn’t it just cancel out? Well, if you have been a runner, you will know it is not like that. It is always harder running in the wind, so you never gain from running in the wind what you lose by running into it. We can prove that with a little bit of mathematics.

There is the drag force on you, if the wind speed is w and you are moving at v, it is proportional to the square of the difference. What is the power that you need to overcome that? Power is force times velocity, so we just have to multiply this by another power of the speed, so it goes up to v minus w cubed. This is pretty non-linear, and that is the key to what happens, this cube.

Let us idealise our track to be a square. It does not make any difference, but it saves us doing a nasty integration. We imagine we have got a square lap, so we run along leg one, up along leg two, along leg three, and down leg four. For simplicity, we will imagine that the wind is going horizontally. This means that, when you run across one leg, you will have the wind behind you, and the power you need will be just k, the constant of proportionality, times v minus w cubed. When you go up the next let, the wind is neutral, a cross-wind, which does not affect you at all, so you just need kv cubed. When you run along the third leg, you are going into the wind, and you need v plus w cubed of power to overcome it. When you come down the next leg, the wind is neutral again. So what is the total power that you need for a lap? You just add the four things together. You have got four kv cubes, one from each one, and the minus signs cancel out, and you get three vw squareds, and another three vw squareds, and so the answer is four kv cubed plus six vw squared.

You see two things about this. First of all, it is w squared, and if I change the wind speed to the opposite direction, to minus w, the answer will be exactly the same. Running the other way round would not make any difference. But you can also see that if there is no wind, the power you need is four kv cubed, so whenever there is a wind, the power needed is always bigger than four kv cubed. If you make the wind go in any angle you like to the horizontal, you can do the calculation, you will find that angle completely cancels out, and you get exactly the same answer, multiplied by cos squared of the angle plus sine squared of the angle, which is one. This is true for any wind direction, and it simply means that it is always slower running round laps in the wind than in still air.

In the last year, there was an odd phenomenon of a wind-assisted marathon at the Boston Marathon, concerning Geoffrey Mutai, not to be confused with another Mr Mutai who won the London Marathon the following day, who was another Kenyan athlete, but not a relative. Geoffrey Mutai took more than 2.5 minutes off the world record in his performance in the Boston Marathon, with 2hrs 3m 2s, and the second runner, another Kenyan athlete, was four seconds behind, also way, way ahead of the world record. The Boston Marathon course is very strange. It is not like the London Marathon and all over top marathons. It does not have many laps. It is a single point to point course. And it is not valid for record purposes because there is a rule that, if you have a point to point course, then the finish must not be more than 42m lower than the start. You can guess why. There are strange marathons in America that people seek out, where there is enormous variations between the start and the finish height, for example about two miles, so you can run your marathon in about an hour. The Boston course drops 139m from start to finish. It has some hills in between, so it is not quite as bad as it sounds. What happened in this marathon was that it was very windy, and it was clear that, in effect, the runners were running an entire marathon with a strong wind behind them.

One of the most interesting comments, when the winner was asked about this, was that he said he did not think that was the case. “I never felt there was any wind,” he said, which I thought was an absolutely conclusive remark. Because, remember what the drag force looks like, that we just discussed, proportional to the density, proportional to the speed you are running, minus the wind speed. So if the wind speed is the same as the speed at which you are running, you will not feel any drag force. In fact, there were then independent reports from people around the course, saying that they thought that there was a wind speed of around 5m per second or so, and it was quite blustery, behind the runners. If you look at the winner’s average speed, a time of 2h 3m over his marathon course, lo and behold, the average speed is 5.7m per second. So, in fact, the following wind was very, very close to his average running speed. In effect, he might therefore have been feeling no resistance.

The situation is a bit more subtle, but when you use the formula that we have looked at, what you estimate is that, if he is just running on his own, with no one around him, he has got a 3% power saving over the race, which means that this fantastic time of 2hr 3m is equivalent to 2hr 6m 45s, without that extra assistance.

We might be being a bit harsh on him. We are assuming that he has always got the wind at his back, blowing him along. If you look at pictures of the race and film, he is running in a group for the first half. People always think about athletes and cyclists shielding themselves from the wind by hiding behind competitors, but you do not want to be in front of people because that is stopping you feeling the benefit of a following wind. So he might not have had the full benefit of the wind in the first half. In the second half, where he breaks away from everyone else, he does have the full benefit. If you look at the split time for the second half of the race, it is quite astonishing: 61m 4s for the half-marathon, for the second half. It is quite amazing, and obviously wind-assisted. So if we take that detail into account, he is really running 2hr 4m 52s, which is still extraordinary, but a little bit of analysis of what is going on shows you that wind is really very important. The current world record, by the way, has since been reduced, on a lap course, to 2h 3m 38s.

If we think about how we allow for wind assistance in 100m sprinting, you can work out the power you need, the typical sprinter weighing about 70kg. We want to know the density of air, that was the other factor, that area that you are presenting to the wind, so we know all the numbers. When we put them in, about 3% of the runner’s effort power-generated is going into just overcoming the air through which he is moving.

If we just do a little bit of algebra, we can then calculate if there was a wind w, what would the time be that you would take to complete 100m, compared with the time that you would take if there was no wind? It is a rather simple formula. The 0.03 is the 3%. So there is the time you would record if there is no wind, and if you consider the wind speed, the time that you would record if there is a wind w. If the following wind is positive, w would be positive. If you are going into a wind, then the minus becomes a plus.

Many years ago, I remember writing a short article which derived this formula and then applied it to the top 10 100m runners of all time, changing all their performances to what they would have done with zero wind, and the result is rather interesting, because the fastest runner in the world was not the world record holder. Because the world record holder had set his record with the wind just below the valid 2m per second, whereas there were other performances with essentially no wind, that were just a hundredth or two hundredths behind, they were far, far superior.

What about Mr Bolt? What is the wind situation with him? This is rather remarkable. Although he is a very slow reactor to the gun, he has had almost no help from following winds in his record performances. That last formula tells you a usual rule of thumb: for each one metre per second of following wind, you get an improvement of about 0.1 of a second on the finishing time. So, if you run 10s flat, with a 1m per second following wind, this is worth 10.1s in still air. When Bolt ran 9.69, the wind was actually zero, so there was no wind at all. If someone had opened the doors in the stadium behind him and let in a 2m per second following wind or turned on a big fan, or a jet engine, behind him, what would have happened? His 9.68 would have turned into 9.48, without him having to generate any more power. That is what I mean by “improving without running any faster”, without doing anything physiologically different.

In Berlin, when he ran 9.58, there was a following wind, but it was not that dramatic, it was 0.9m per second. In this case, if you had bumped that wind up to 2m per second, it produces 9.47. These two performances, although they look 0.1 of a second different, are intrinsically very similar, almost identical when you allow for the two winds. But you can see how much better he can do just if he has a lucky windy day!

Wind is all very well, and you notice that people worry about records plus or minus a hundredth of a second, but how accurately is the wind actually being measured? When you look into this, you find that this is the great weak point of modern track and field athletics technology. The limit that we have got of 2m per second was something that was adopted back in 1936 by the International Athletics Federation, and it is somewhat arbitrary to us today, but it had a rationale at the time. It derived from the fact that they were timing by hand then, and the greatest accuracy was 0.1 of a second. So they wanted to rule out the possibility that the wind assistance would create a record with a change of plus or minus 0.1 of a second. Today, now that you are keeping records to 0.01 of a second, you really need to know the wind speed as accurately as 0.2 of a second, at least. Otherwise, somebody who you think is wind-assisted may not be and may have set a record.

How is the wind measured in athletics? Rather crudely, is the answer! Something is planted in the ground, halfway down the straight, at the 50m mark, and it is at 1.22m above the ground, so that it is going to catch the wind where the athlete’s torso is hitting, and it is 2m or less away from the side of the track. If you have walked down by the start of a track with a big stand, you will know that there is huge variation in the wind, caused by the presence of the stand and the change in the seating levels around the edge of the track, and the wind also varies along the straight. It can be rather different at one point to another. So, in practice, the accuracy of a wind gauge over the period of the race is really somewhere between 0.2 and about 0.5m per second. It is not really consistently as good as this. And where you put the wind gauge also produces a different result.

I have seen some research that was done on this by Linthorne at Brunel University. It includes a plot of the official wind speed measured by that wind recorder at the 50m point, compared with wind readings that he obtains by putting another recorder at the 30m point, and he does other experiments with it at the 70m point. If the wind speed was consistent all the way along the race, all the data points would lie along one line and you would have the same wind speed at the two points. Even if you are not a statistician, you can see that this isn’t really the case, there is very significant variation in the measurement of the wind from wind gauges in the two locations. If you are running a 200m race, there os an entirely different problem to worry about, with the bend and the straight conditions.

The last thing I’m going to discuss about wind and records is a notorious problem. We have talked about the men’s world record. Alas, the women’s world record is fraught with problems. It stood for a very long time It was set by Florence Griffiths Joyner, known as Flo-Jo, who died of a heart attack a few years ago, and her world record that no one has really ever got anywhere near, either before or since, is supposedly 10.49s.

This was set in 1988 at the American Olympic trials. Flo-Jo went on to win the Olympic Games 100m and set the world record in 200m as well. At those trials, in the semi-final stage, with a wind reading supposedly of zero, she ran this 10.49, which broke the world record by 0.27 of a second. At the same time we know that, just parallel in the jump runways, the long jump, triple jump, jumps were being measured as having 4m per second following winds, and the next semi-final that came up after hers, a couple of minutes later, had a 5m per second following wind. I think the charitable conclusion is that there was a failure of the wind gauge. This was a wind-assisted performance. The other athletes in the same race also experienced dramatic improvements over their performances in the first round and in the final. In the final, there was a 0.9m per second tail-wind. Flo-Jo won, with a winning time of 10.61. That probably is what the real women’s world sprint record should be. It is still the next best performance of all time.

Another place that has become rather topical because of wind assistance and hindrance is the new velodrome at the Olympic site in East London. You have probably read some of the press reports. I was trying to get more information about the geometry and construction of this cycling track, but I was told by the designers that it was a commercial secret and they were not going to tell me! One of the things that we do know is that there is going to be a heating of the air at track level in the velodrome, so if you have got tickets and you are sitting near the front, you may not want to take too much extra clothing, or you could just give your tickets to me!

Why would they be doing this? We know the answer from the formulae we have been looking at. Remember what the drag force is when you move at speed v through still air. It is proportional to the speed squared, but it is proportional to the density of air. One thing everybody knows about density of air is that hot air rises, because it has a lower density than cold air. So, by heating the air down at track level, you will lower its density, you will decrease the drag force on the cyclists, and they will go faster. They will have a greater chance of setting records. This is the same for everybody. It Is not unfair in any way, but there may be other problems with it. I have a little plot, taken from a Physics book. It shows the density of air, around the relevant area of temperature, so that you can see what the magnitude is. You are playing around with the second decimal place in the density, over a significant range.

What does that mean? The drag force is worth about 1.5s to Bradley Wiggins over the 4km pursuit, which is the equivalent of the mile in time for the cyclists, which is quite significant when you are moving at that speed. So this is a way to try to cheat the record books. You might argue that, just as in athletics when you have a wind-assisted performance, or an altitude-assisted performance, those records are in some way ‘starred’, they are marked as being special in that way, that any records that you set in London should be starred in this way as being wind-assisted.

The drag changes over temperature ranges, as you move at different speeds. Because of the speed squared factor, the effects get much more pronounced in the shorter events where you go faster, rather than in the longer events, where there is a cumulative effect.

The last tip for Mr Bolt is to run high. That is go to high altitude. Altitude was something that came into the world of athletics in 1968, when the International Olympic Committee, in their wisdom, decided it would be a good idea to hold the Olympic Games in Mexico City, at a height of 2,250m above sea level. This produced a storm of controversy and lots of leading athletes just did not go because they felt it was so biased against people who were not born at altitude.

What is happening of course is that, as you go to high altitude, the density of air is being diminished, and so that resistive force, the drag force from the air, is being reduced. Rho air is going down, not through the temperature necessarily this time, but through the air pressure being lower. Each 1,000m that you go up from sea level will reduce the air density by an amount that is worth about 0.03 of a second for 100m sprinter, compared with sea level. So in Mexico City you are looking at a 0.07 of a second advantage over sea level performance.

The Mexico City Olympics were revolutionary and innovative in many ways, not just through being at altitude. They were the first where there was fully electronic timing, the first where there was drug testing, the first where there was gender testing, and also the first where there was an artificial track surface. At the Tokyo Olympic Games, they still used a cinder surface; here, they used rubberised so-called tartan surface, much more reliable, much faster, dramatically better for people like triple-jumpers. There were a huge number of world records in Mexico City and, on average, the track sprint records were improved by about 1.7%, much bigger than you would expect just from the altitude alone. The nice track surface and so forth must also therefore have been a contributory effect.

To get a picture of that, if there had been a 2m per second following wind, it helps you by 0.2 of a second, so going up to this altitude helps you by 0.07, so it is not as much as having a following wind but it is still significant. Of course, if you were in the distance events, for other reasons the effects of the altitude were disastrous if you were not acclimatised and used to it, and times were far, far slower in those events.

Our final recommendations for Mr Bolt is that what he can look to hope for is, by improving his reaction time, by being a little more alert and responsive and concentrating better and doing the type of psychological training that sportsmen do to try to respond more quickly, he can look to improving maybe by 0.03. He could also try to take advantage of 2m per second following winds because there are certain stadia in the world that you know are always windy. Also, he can try and race as high up in the air as he can, in high altitude venues.

What would that mean? His 9.58s record, which so many people think is totally unapproachable, just from his reaction time improvement, he could reduce it to 9.55. If he allowed himself the maximum following wind, he goes down to 9.44. If he goes up to Mexico City, then he is down to 9.37, all without any actual extra improvement in his sprinting ability. You can see, he has really got a lot of scope to take this record a long, long way down. And, he tends to run the 200m about twice as fast as the 100m, so you are looking at about 18.7.

As a final comment, to take the wind out of his sails a little bit, at the end of the season, he has really found that he was perhaps no longer the fastest man because his training partner, Nathan Blake, ran a 200m in 9.26s. At first, you think, this is a little bit slower than Bolt’s world record of 19.19, but Blake had a fantastically slow reaction time, 0.2 of a second. When you allow for that, Blake actually runs faster now than Bolt, so his running time over 200m is faster than Bolt.

I hope that when you watch these races in the future, you will have a little more insight, know a little more, and have got a feeling for what is going on and why people worry about wind speeds and reactions, and what the effect actually is on record performances.

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