THE SCIENCE OF SWING?

Cricketers think they can explain the most lethal and seductive art in the game without recourse to the laboratory, though researchers beg to differ.

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The ritual is always the same. Arrive at ground; drop bag in changing room; head out to the middle; and then spend a good 20 minutes peering at the pitch first and then the sky. After a bit of cursory prodding and poking below and sniffing of the elements above, there will be nods all round. Yes, it is a good day to bat. Or, it feels like a bowling day.

Cricketers are an unscientific lot, relying more on feel and cricketing folklore to try to evaluate what are, after all, crucial elements of the game. For, more so than any other sport, cricket is dictated to by conditions, the balance between bat and ball tipped this way or that by a pitch that will be friendlier to batsmen or bowlers and conditions that will or will not favour the latter. And within the course of the game, even the greats will be dictated to by conditions.

Swing is just one factor in this equation, albeit a crucial one. If the ball swings, batting becomes more difficult, for the obvious reason that a ball coming down at 80mph or more is harder to hit when it is moving laterally in the air. Swing, though, is a mercurial thing, no matter what the scientists say. Some days it does, some days it doesn’t and it pays to try to be bowling when it does.

There are three types of swing: conventional swing, reverse swing and contrast swing. For the benefits of simplicity we will concentrate on the first two.

Conventional swing occurs when one side of the ball is shiny and one side rough and the air drags on the rough side of the ball. It stands to reason, although scientists may tell you otherwise, that moist conditions are helpful in this context. The heavier the air, the more drag there is likely to be on the ball. Swing bowlers, therefore, enjoy humidity; batsmen prefer breezy, fresh conditions.

But conditions are only one part of the equation: just as or more important is the skill of the bowler. You can have a ball that is as shiny as a conker on one side and rough on the other and the atmosphere can be pregnant with swing, but if the bowler hasn’t got the skill then it is all for nothing.

Wrist position is vital: through his wrist position, the bowler will be able to cant the seam in delivery — towards first slip for the outswinger, towards leg slip for the inswinger — so that it acts as a rudder. He will also want to release the ball as late as possible, off the tip of his middle finger, so that the seam is rotating backwards in delivery. Finally, he must have control of a full length, so that he gives the ball maximum time to move in the air.

There have been magnificent practitioners of this skill down the years, although with drier conditions as a result of the covering of pitches in the last three decades it is becoming something of a lost art. The best conventional swing bowler in the world today is Jimmy Anderson of England who, when in form and when conditions are in his favour, can be unplayable. Think of Trent Bridge, a ground that because of its closed-in atmosphere is a favourite of Anderson’s; think of the flags fluttering, so that a breeze is blowing over his right shoulder; think humidity. Now watch how a bright red stripe develops on his trousers as he shines the ball furiously, caring for it like an ancient family heirloom. Now watch as the
ball snakes malevolently in the air, with just the merest tilt of his wrist, this way and that, and watch as a succession of batsmen grope at the ball, unsure which way it is swinging. At its best, it is the most alluring of all cricketing skills.

Although the understanding of it is a relatively recent phenomenon, reverse swing — so called because the ball swings in the opposite direction to that which is expected — has been practised by bowlers used to bowling in the type of arid conditions that are most often found on the sub-continent. The masters of reverse swing are the Pakistanis and the story goes that the knowledge of it was passed down from Sarfraz Nawaz to Imran Khan to Wasim Akram and Waqar Younis — the two greatest exponents of the art — and then on to their current day equivalents, Umar Gul and Mohammad Amir.

Because Wasim and Waqar spent so much time in English county cricket, their secrets are now well known and widely practised around the world. Whereas conventional swing works in humid, moist conditions, reverse swing occurs when dry, hard pitches or — let's not mince words here — fingernails create one side of the ball that is much rougher and coarser than the other. At a certain point and at a certain speed, the ball starts to swing in the opposite direction — ie, towards the shiny rather than towards the rough side. Reverse swing works best when the ball is propelled quickly and with a low, slingly and fast arm.

The theory of swing is known well enough by cricketers, but because it — especially conventional swing — is a mercurial thing, there are many old wives’ tales that are thought to better encourage swing, old wives’ tales that scientists would no doubt dismiss. Bowlers have been known to apply all kinds of materials to the ball — the laws of the game allow for just sweat — such as lip salve or lip gloss to create shine, or even, dare I say it, to use dirt from the footholds to create a drier, rougher surface than would otherwise be possible.

In my last couple of years in the game, the trend was for the fielding team to suck on mints or sweets, because sugar in the fielders’ saliva was thought to help the ball swing. Chewing gum helped too, although when one young twelfth man was sent to buy some and came back with a packet of Orbit, the sugar-free gum, he was sent away with a flea in his ear.

Bowlers insist that the ball is important and, invariably, choose the one that feels smallest in their hands and looks darkest. Dark leather, they say, shines better. Older bowlers insist that modern cricket trousers shine the ball less well than old flannels, so some bowlers have been known to cut a piece of old flannel into their modern trousers. And then there is the difference between machine-made balls, such as the Kookaburra in Australia, and handmade British balls, such as those made by Duke. The English balls swing more, they say.

The scientists will tell you that all this is rubbish. That on any given day, on any given ground and in any conditions, a competent swing bowler who presents the seam correctly should be able to swing the ball. We cricketers know that not to be the case. Some grounds swing more than others; some balls do, some balls don’t (which is why bowlers will not let batsmen anywhere near the picking process). Sometimes it just feels like a swinging day, sometimes not. Besides, if we were to listen to the scientists, what would there be to talk about during that morning ritual when the pitch is prodded, the air is sniffed and the past tens for the day dissected. Will it swing or not?  

What science says about swing, page 40

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If the rules of cricket are confusing to non-cricketers, the science of swing bowling can be equally as testing to non-scientists. Bowlers may be able to deliver the perfect outswinger one day, but when the ball fails to move the next, they sniff the wind, raise their eyes to the sky and complain that the cumulus weren't sufficiently nimbus. Is that a reason or an excuse? Does humidity really affect the performance of a ball flying at 80mph? And what makes it swing in the first place?

Fortunately, there is a significant and motivated Venn overlap between scientists and cricket nuts. These people are devoted to understanding the aerodynamics of the humble cricket ball. Papers on the science of swing bowling have been published in journals across the world, from the Proceedings of the Royal Society to the Mathematical Gazette.

It started with Isaac Newton, who wrote about the curved flight of tennis balls in 1672. Fifteen years later, he set out his Laws of Motion, which determined that a moving object not subjected to any force continues to travel in a straight line. Since the ball that is bowled by Jimmy Anderson at Trent Bridge on the first day of a Test is patently not travelling in a straight line, it must therefore be affected by differing forces on either side.

The late Raymond Lyttleton, an Emeritus Professor of Theoretical Astronomy at Cambridge and a fine cricketer, was the first modern scientist to calculate the forces at work. "The atmosphere presses on everything with a force of around one kilogram per square centimetre of surface," he wrote in Don Bradman's The Art of Cricket.

"So on a cricket ball, the opposing pressures on any two hemispheres are each about 40kg. If by any means some kind of pressure difference [between left and right sides of the ball] could be brought about, so that these opposing forces failed to balance by even as little as one part in a thousand, a sideways force of 40g would come into play. This... could easily make the path curve sideways... by about 30cm during the time the ball is in the air for fast bowling."

That is swing bowling, as opposed to spin bowling, in which the movement of the ball is dictated by the way it is thrown, by that delicate twist of a Shane Warne wrist that can cause it to spiral through the air at a deceptively gentle pace and spin off the ground in unimaginable directions. Swing bowling, whether conventional, reverse or orthodox, requires speed rather than spin. Its movement is created and dictated by this pressure differential between either side of the ball and that, in turn, is in great part caused by the seam.

The cricket ball was created in its present form in 1780. It has a cork core, (normally red) leather skin and a weight of between 155.9 and 163g. What makes it distinctive is the primary seam — six rows of prominent stitching around its equator — which prevent it from being a perfect sphere and make its behaviour in the air variable and interesting.

Without the seam, there would be no opportunity to create a pressure differential. When a ball moves through the air, the air closest to its surface sticks to it and travels with it. Just beyond this is a layer of air about a millimetre thick — known as the laminar boundary layer — that marks the boundary between the air that is moving with the ball and the undisturbed air around it.

At slow speeds, the laminar boundary layer clings to the surface of the ball, surface almost round to the back. The faster the throw (up to a critical speed), the earlier the layer detaches from the ball, flowing out to either side like the wake of a boat. With a perfectly spherical ball, the wake is symmetrical, but if there is some physical barrier — a seam — that breaks the laminar boundary layer earlier on one side than the other, the ball swerves, or swings in the opposite direction.

When the ball is released from the bowler's hand with the seam at an angle to the direction of flight, those rough little stitches trip the laminar boundary layer into turbulence on the seam side. This increased energy causes the air to cling on to the ball for longer, exerting a greater pressure, while the non-seam side remains undisturbed and separates further forward. The ball swerves away from the seam side. So for an inswinger, the seam is angled towards fine leg (a right-handed batsman's left); for an outswinger, towards the slips (to the right).

It stands to reason, therefore, that the larger the difference between the two sides, the higher the pressure differential and the greater the swing. The air has to glide past the smooth side of the ball like an ice skater and bump against the seam side like a mountain biker on a rocky path. That is why the new, shiny ball that has been rubbed to a lacquered gleam swings best, and why it is sometimes hard for a bowler to resist picking at the seam with their fingernails.

Up to a point. Swing is also determined by speed. The current authority on cricket-ball aerodynamics, Dr Rabindra Mehta, who is a Nasa scientist and an old school friend of Pakistani bowling legend Imran Khan, has calculated the optimum bowling speed for swing. In a 14-page article on cricket-ball aerodynamics, he wrote: "The maximum pressure difference between the two sides occurs at ... 29m/s (65mph), when the boundary
Swinging balls

WHEN IT SWINGS...

 firmware's line of flight Laminar boundary layer Sideways force

AND WHEN IT DOESN'T

Ball's line of flight Laminar boundary layer Turbulent boundary layer

VIEW FROM ABOVE

The ball's seam disrupts the laminar boundary layer (smooth airflow) creating a turbulent boundary layer in which the air is chaotic (shown in grey). This air separates from the ball later than the smooth air, lowering the air pressure on that side and creating a pressure gradient. As a result, the ball moves away from the high pressure to the low pressure, i.e., it swings.

VIEW FROM ABOVE

On a warm, sunny day microturbulence (shown left) disrupts the laminar boundary layer making the smooth airflow turbulent. This means both layers are now turbulent, eliminating the pressure gradient and, therefore, swing.

VIEW FROM THE SIDE

layer on the seam side is fully turbulent while that on the non-seam side is still laminar.

Beyond 65mph, the swing starts to decrease, as the speed itself creates enough turbulence to move the point of separation of the laminar boundary layer and equalise the pressure on either side of the ball. As the speed increases further, however, the forces at work start to flip; the turbulent boundary layer on the seam side begins to separate earlier than the non-seam side, setting up an asymmetric pressure. This creates reverse swing, in which the ball swings away from the seam.

In order to calculate the forces at work, Mehta set up a series of experiments in a wind tunnel. A ball was mounted in the tunnel and smoke was injected into the separated area behind the ball — the wake — while a wind was blown at varying speeds. The smoke clearly showed how the seam tripped the boundary layer into turbulence on one side, while on the other, non-seam side it flowed past smoothly. As the wind speed was varied, the separation point moved along the ball.

Mehta's determination to solve the science of swing has taken him to the great cricket grounds of the world — in the name of research. He realised that some bowlers, Andrew Flintoff of England among them, were able to swing the ball effectively with the seam pointing straight up, and not angled towards or away from the batsman. Their effectiveness at what he called "contrast swing" is caused by the contrast between the rough and smooth sides of the ball and determined by speed. At a relatively low speed (less than 70mph), the boundary layer over the smooth surface of the ball remains in a laminar state and separates early, while the air travelling along the rough side becomes turbulent and separates later. The resulting side force makes the ball swing towards the rough side. At speeds of more than 70mph, the effect is reversed: the boundary layer on the rough side separates earlier and the ball swings towards the smooth side.

The science of swing is comprehensive and convincing, leaving little room for the gospel according to Athers, that "the heavier the air, the more drag there is likely to be on the ball". According to Professor Sharan Majumdar of the University of Miami, "any claim that humidity is important is equivalent to a claim that the Earth is flat".

Majumdar learnt his swing science at Cambridge, when he watched Test matches with Ray Lyon. He has maintained a website on The Swing of a Cricket Ball for 15 years. A meteorological expert, he has a keen interest in the affect of atmospheric conditions on seam bowling. He is convinced that there is another force at work.

"Small-scale turbulence around the ball is the key," he says.

"Microturbulence is created when the sun warms the soil and grass, producing small spikes of warm air rising from the ground. If there is a higher degree of microturbulence, the differences in the air layer separation around the ball become diminished."

So if it is dry and sunny, microturbulence may be greater and the ball will swing less; if it is overcast, the ground is damp and there is less microturbulence, the ball will swing more.

Which makes the cricketers right about the cumulus — for the wrong reasons. Clouds are good for bowlers not because they bring humidity but because they can diminish microturbulence. All that pre-match prodding and sniffing, it seems, may have some point, though possibly not as much as a quick physics primer and a detailed weather report.