BIOMECHANICS OF THE LAWN BOWL DELIVERY MOVEMENT

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General Evolution of Lawn Bowl Delivery Method

Stances in Target Sports.

The delivery movement in virtually all target sports (e.g. archery, billiards, bocce, bowls, croquet, curling, darts, golf, pistol, rifle, snooker, tenpin) is one of hand and eye coordination. The closer that the plane, or direction of the manual delivery movement tracks the line of aim, the simpler is the task of accurate hand and eye coordination. Performers can achieve such conjunction of the plane of movement with their line of sight in two ways.

One method involves a front-on stance, so that the arm has an unobstructed swing backwards and forwards. The delivery posture may involve a sideways lean of the upper body to reduce the separation between the aiming line and the delivery line. A front-on delivery is usual in bocce, bowls, croquet, darts and tenpin. The other method involves a side-on stance and sideways aiming technique, which is usual in golf and archery to allow effective use of the club and bow, respectively.

Restraints on Allowable Lawn Bowl Delivery Method

The laws of lawn bowling (in Australia) require bowlers to adopt a stationary stance with both heels forward of the rear of the mat and the whole of one foot on it, before beginning the delivery movement. Until release of the bowl, one foot must be entirely on or over the mat. Thus, only after the instant of release may a bowler resume any forward movement. The laws also require bowlers to deliver jacks and bowls from a 60 cm by 36 cm mat. The mat not only provides a visible delivery zone, but also protects the playing surface.

To protect their greens from impact damage, bowling clubs commonly require bowlers to release their bowls within a few centimetres of the playing surface. To avoid ‘dumping’ deliveries, the adopted release posture should have the delivery shoulder no more than the length of the extended arm above the playing surface. Bowls released too high make an audible thump as they make contact with the green.

Statics and Dynamics in Lawn Bowl Delivery Technique

Differentiation of statics and dynamics is a useful basis for studying bowling technique. Dynamics is about the forces that produce movement. Thus the dynamics involved in bowling, that is the forces that produce mechanical movement, centre on the bowl itself, the grip and the delivery arm. Statics is about the forces that produce mechanical stability, balance, or equilibrium and which originate in the other parts of the body. Their primary function is to provide a stable framework for supporting the delivery arm fulcrum, or shoulder. Arguably, the more remote a body part is from the bowl, the less critical it is during delivery.

Dynamic Forces and the Derivation of a Performance Model

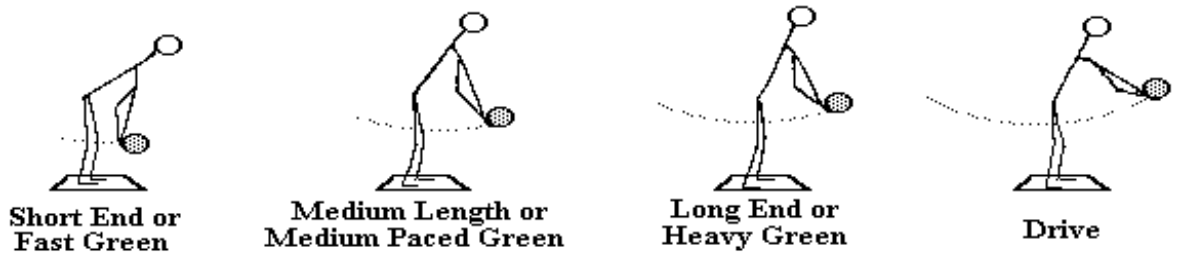
Common Objective of Deliveries

In general terms, the objective of each delivery is to propel the bowl so that it comes to rest as nearly as possible to the jack or other intended position in the head. The objective of an attacking delivery is to dislodge a stationary bowl or bowls before the disturbing bowl would otherwise come to rest at a point beyond that of the target, and perhaps even beyond the confines of the green. Bowlers can execute attacking shots by judging the required line and impact speed to disturb the target, by estimating the extended pathway along which the bowl would continue before coming to rest were its pathway uninterrupted, and then by visualising an object (e.g. a jack) at the notional end point of bowl run. The attacking task thereby becomes a draw shot to the visualised object, and is little different from any other draw shot. Consequently a model for virtually any lawn bowl delivery should be based on the mechanics of displacing a bowl from its point of delivery to the notional end of its run.

> ‘Attacking shots are simply draw shots in disguise.’

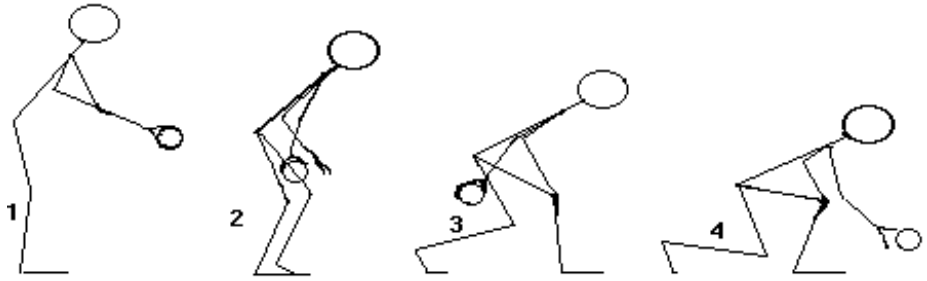
Acceleration Of The Delivery Swing - Muscular Force And Gravity

In Australia, bowls instruction has tended to ignore any role for hand and eye coordination, or for the powerful musculature of the delivery arm and shoulder in the bowl delivery process. The so-called 'theory of elevation' would have bowlers would have bowlers controlling the height, or forward elevation of the bowl and arm during the stance. It postulates that the initial elevation determines the rearward elevation at the peak of the back swing, which then determines the bowl release speed. The adjacent sketches illustrate the point.



The 'theory' likens the delivery action to the swing of a pendulum, and advocates correction of bowl run distance by conscious adjustment of starting elevation, or height of the bowl. The concept has some practical difficulties, which may explain why it has attracted little favour in other bowls-playing countries. Once bowlers have acquired an efficient and consistent bowl delivery action, delivery preparation should focus on the objective of deliveries, and not on the limb and body movements needed to execute them, which should be automatic. The adjacent sketches show that perhaps 50% of the starting height or forward elevation (sketch 1) will have been lost when a bowl pauses momentarily at the peak of the back swing (sketch 3). Because of their individual technique, some bowlers have a back lift appreciably less than 50% of the initial elevation.

Avoid conscious attention to delivery arm elevation



The armpit derives its shape from two large tendons. The one at the front attaches to the upper arm a short distance down from the shoulder. It links to a powerful group of muscles that fans out over the front of the rib cage. These muscles contract in the forward swing. The tendon behind the armpit likewise attaches to the upper arm. It links to a powerful group of muscles that fan out behind the rib cage. These muscles contract in the back swing.

'Generate bowl delivery speed by intuitively integrating muscular force with gravity force.'

It is impossible to isolate muscular functioning so as to produce a gravity-powered 'pendulum' swing. During both rearward and forward phases of the arm swing, even novice bowlers intuitively integrate muscular force with gravity force. Further, bowlers intuitively tend to vary those forces in unison. For example, for a short end on a fast green, bowlers tend to reduce not only applied muscular force, but also the amount of back lift, or elevation. For longer ends, or slower greens, bowlers produce greater bowl release speeds by intuitively integrating a number of variables. These include employing greater muscular force, extending the back swing, accelerating the delivery movement, and extending the advance of the front foot to enhance stability during the extended

'Muscular force is the primary source of bowl momentum.'

movement. Once back lift or elevation at the peak of the back swing is maximised, gravity offers no additional contribution to bowl delivery speed. Production of high bowl release speeds typically requires considerable muscular force.

The delivery process generates feedback that includes a neuro-muscular sensation of, or 'feel' for the action. Bowlers use this neuro-muscular activation to regulate or adjust bowl release speed, and consequently bowl run distance. This is an aspect of a hand and eye coordination process.

There is considerable disparity in they extent to which even international bowlers use gravity force to augment bowl delivery momentum. Some bowlers have free-swinging deliveries; others have a compact arm swing and a 'pushing' action. A few bowlers accentuate a pushing action by flexing the elbow as the bowl approaches the release point. The explosiveness of a pushing delivery allows less scope for making any intuitive adjustments to arm movement. 'Pushers' make little use of bowl elevation, and intuitively employ greater muscular power in their delivery action. With comparable practice and experience, they achieve results of comparable accuracy.

A definite follow-through phase should occur after the delivery movement and before the recovery to an erect posture. Bowlers who lack a follow-through phase may start an anticipatory reduction in arm acceleration even release of their bowls. This error typically results in short bowls because of insufficient release speed.

Arc Length Of The Forward Swing

The upper arm joint has a range of motion of about 230°, which exceeds that of any other joint in the body. In an erect posture, the back swing limit is not far past the hip. The more bowlers incline their trunk and shoulders forward and down, the more they can extend their back swing limit rearwards. Trunk inclination thereby correspondingly extends the available length for the forward swing. The virtual limit of the forward swing is the point where the hand reaches the lowest point of its arc, directly below the shoulder. According to step length, this position is typically near the toe of the advanced foot.

"A free back lift minimises any need for 'pushing' of bowl deliveries.'

Therefore the back swing limit primarily determines the available arc length of the delivery arm for its task of generating bowl momentum. At the limit of the back swing, the bowling arm is momentarily stationary. A bowler must give the bowl sufficient angular acceleration so that when it reaches the release point, it will have sufficient momentum for the delivery. Depending on the environmental and tactical demands at the time, the required release speed of the bowl is typically in the range 10 – 30 kph. Bowlers can ensure that a generous back lift is within their range of movement by adequate forward inclination of the trunk. If they have good back lift, they can reduce the need for explosive muscular force to generate required arm speed. A more even balance between gravitational acceleration and muscle-powered acceleration enhances the scope for more fluency of movement, and for intuitively, delicately, and accurately adjusting that movement should the bowler sense the need.

Simultaneous Shoulder Advance

A simultaneous advance of the shoulder can, to a minor extent, augment the forces that produce bowl delivery speed. There is a partial advance of the shoulders during the back swing as the opposite foot moves forward. There is further advance of the shoulders as knees and ankles flex, the lowered trunk glides forward, and the delivery arm accelerates during its forward swing. It is during the latter phase that shoulder advance has the potential to contribute to bowl delivery momentum. Body weight usually moves when the shoulders advance, so use of good technique will avoid an unstable delivery posture. A sustained follow-through after bowl release usually indicates effective use of shoulder advance.

'A smooth follow-through usually indicates optimum use of shoulder advance.'

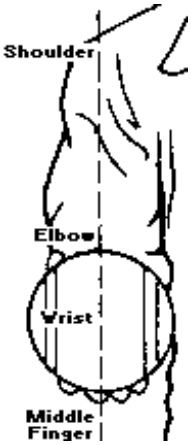
Negligible augmentation of the forces producing bowl momentum by advancing the shoulders can occur in a delivery from a fixed stance. From the 'set' position in a fixed stance, movement of only the arm is available for generating dynamic force. Nor does augmentation occur where the timing of any shoulder advance does not coincide with the forward movement of the delivery arm. Any contribution to bowl release momentum due to shoulder advance would rarely exceed 10%. Rapid shoulder advance that typically

'Delivery of a bowl is an exercise in hand and eye co-ordination'

occurs during in fast deliveries tends to be matched by a proportionate increase in muscular force.

Direction of Bowl Delivery

Delivery of a bowl is an exercise in hand and eye co-ordination. A bowl will initially follow the line of movement of the bowling arm. This result requires a stable delivery posture with no tendency for sideways overbalancing and consequent drifting away from the intended line. In the set up, or stance, bowlers can check delivery arm alignment by one or two trial swings to ensure that the arc of movement tracks the aiming line. The arm alignment should form a right angle with the shoulder line.



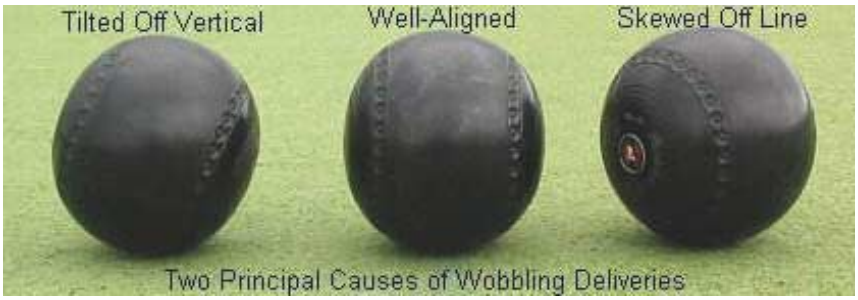
The alignment of the arm is more important than that of the feet.

Some bowlers take more care with the alignment of their feet than the alignment of their arm. Without due regard to the direction of their arm swing, or to the hand and eye co-ordinating basis of bowl delivery, some bowlers assume that their bowl will inevitably run in the direction in which their feet point. Vision-impaired bowlers must sometimes rely on this technique. Should the feet, hips or shoulders be so misaligned that a bowler feels 'twisted' or uncomfortable in the delivery posture, sensory feedback tends to conflict with visual feedback during the aiming process, and accurate hand and eye coordination may become more difficult. Nevertheless, provided the arm is travelling in the intended direction when the bowler releases it, the bowl should initially continue in that direction, irrespective of any misalignment of the feet.

If the arm begins its movement on an incorrect line, a bowler will always face the additional task of regaining the intended line before the moment of release. The most common cause of misdirected deliveries is a set up in which the elevated arm is angled across the body. In helping to support the weight of the bowl, the non bowling hand sometimes causes such misalignment of the bowling arm, as the images above show. In consequence, the back swing is either to a position wide of the hip and outside the correct line, or is swivelled around the hip to a point inside the correct line, as the adjacent images show. A round-armed swing accompanied by hip rotation is likely to pull the bowl inside the correct line. If the arm drifts off line during the delivery swing, the bowler has the additional task of regaining the intended line before the moment of release. To regain the intended line, bowlers tend either to either loop the back swing or converge the line of forward swing so that the intended line is regained in good time.

For directional consistency, bowlers should avoid using bowls that are too large to be readily manageable. They should adopt a comfortable grip that reliably secures the bowl. The grip should enable the hand to transmit propelling force through the centre of the bowl, as the adjacent image shows. Bowlers without disabilities normally achieve this if the end joint of the middle finger is behind the centre of the bowl, and is the last point of contact when the bowl is released. The muscular force it finally imparts should thereby transmit through the centre of the bowl. That should prevent any skewing of the delivery. Further, if the middle finger is in the same plane as the bowl's centre of gravity, the two digits on either side of it can best assist grip strength and stability. However if the last point of

contact with the bowl is other than the middle finger tip alone, the bowl could skew off its intended delivery line.



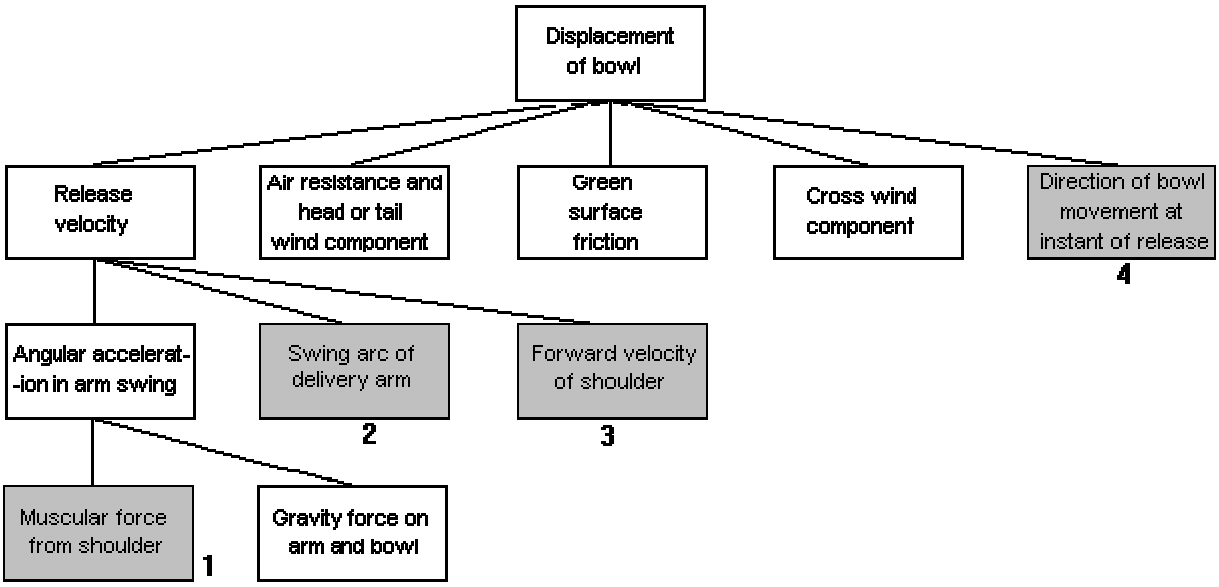
Wobble affects the direction of bowl run. Bowlers can achieve a wobble-free run of their bowls only if their coaxial engraved rings are upright and directed at the aiming point at the instant of release. They should grass their bowls so that these rings are upright and not skewed left or right. Otherwise their bowls will wobble or 'stand up', thereby reducing the effect of the bias. Bowls released too high (‘dumped’) can tilt and turn before grassing and setting out on a line different to the intended line.

Controllable Dynamic Factors Involved in the Bowl Delivery Process.

Thus the four controllable dynamic factors of any bowl delivery process are: the applied muscular force produced in arm and shoulder, the arc of the bowl delivery arm, an extent of shoulder advance, and the direction of bowl delivery. In general terms, the objective of each delivery is propelling the bowl so that it comes to rest at an actual or visualised point in or beyond the head. This is equivalent to displacement of each bowl from the point of delivery to the actual or notional end point of its run.

‘Accurate bowling amounts to accurate line and length.’

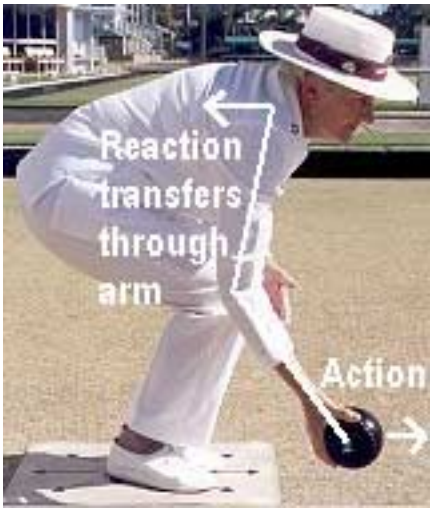
Performance modelling is a conventional way of studying the biomechanics of a sport and optimising its techniques. The following model represents the performing objective of lawn bowling and the factors involved in achieving it. The model is valid for delivery of jacks or biased bowls. The shaded blocks are the controllable factors. Wind, green friction, and gravity are uncontrollable factors. Arm acceleration and release velocity are produced by combinations of the foregoing factors



All controllable factors are capable of being simulated with a bowls testing chute. A video camera with a fast shutter speed option is an excellent tool for observing a bowlers technique for producing bowl momentum.

Static Forces and Implications for Technique

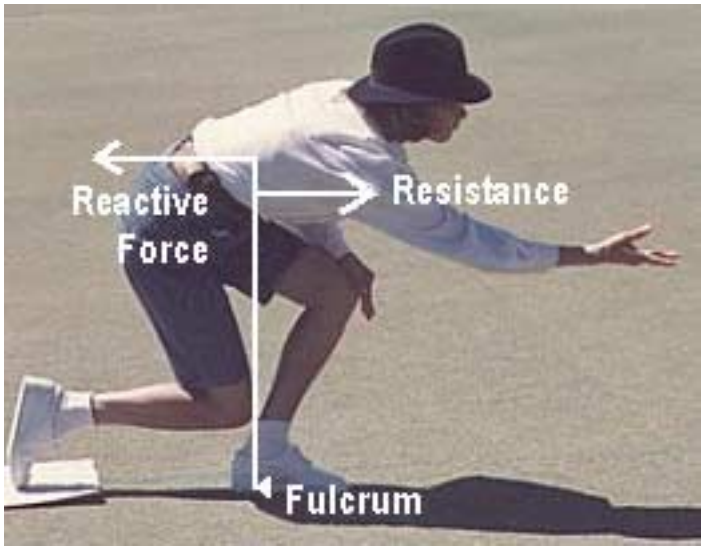
Mechanical Leverage of the Delivery Forces



'For every action, there is an equal and opposite reaction'. (Newton's 3rd Law). A delivered bowl has momentum produced by the arm's angular acceleration, which a bowler generates by intuitive integration of muscular force with gravity force. The complementary reaction is the transfer of rearwards force transmitted through the arm to the shoulder socket, as the image on the right shows.

Contraction of chest muscles that attach to the upper arm, a short distance down from the shoulder produces the muscular component of delivery force. The shoulder joint operates as a fulcrum. The resistance is the combined mass of the arm and the bowl. The centre of gravity of that mass is typically somewhat below the elbow, so the resistance arm is longer than the force arm. (Because of a jack's reduced weight, the resistance arm is somewhat shorter when the projectile is a jack.) Thus, the muscular force component operates through a third-class lever (as in the image on the left), which is the primary mechanism of generating high delivery speeds when they are required. The gravity force component acts through the centre of the arm's mass. Therefore it has no mechanical advantage.

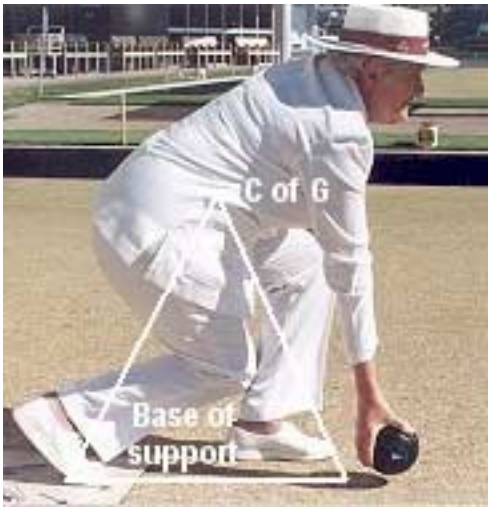
Bowl delivery force results in a rearwards reaction force at the shoulder. This force transfers to another lever that extends through the lower body and legs to the feet, which act as a fulcrum. The resistance to any rearwards toppling motion is the mass of the body, which is typically centred in the belly area, somewhat below shoulder level. Therefore the delivery reaction, or toppling force applies through a second-class lever (as in the image on the right), and has some mechanical advantage.



As the image on the left indicates, the lower the shoulder, relative to the height of the centre of body mass, the less is the mechanical advantage of the toppling force, and the greater is the bowler's stability.

Base of Support

Bowlers' feet form a base of support for their body weight. When the body C of G is directly above the feet, the posture is statically stable. If the reaction force of bowl delivery produces movement that takes the body C of G near the edge of, or beyond the support base, a rearward or sideways toppling of the bowler is typically apparent as jerkiness or stumbling. If the body C of G remains well within the support base, the delivery movement is also dynamically stable. The image on the right shows a stance with a short base of support

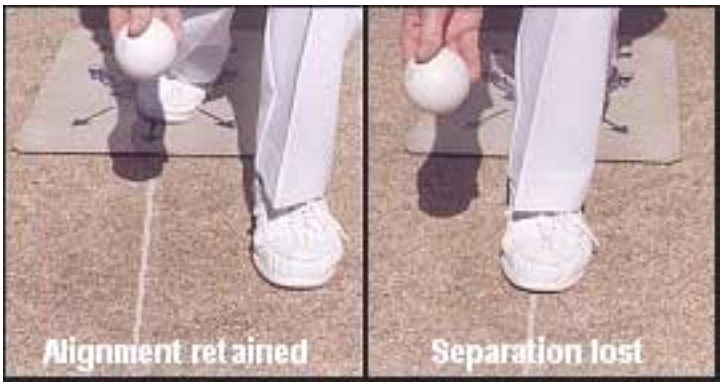


A delivery posture with one foot advanced is virtually universal. As the image on the left shows, this posture elongates the base of support. It provides greater resistance to rearward movement of body C of G as a reaction to delivery force, without compromising dynamic stability. It also allows stable forward movement of body C of G as the trunk inclines forward and the shoulders advance.

The advance of the front foot is optimally about the distance of a natural walking pace. A shorter distance results in reduced length of the base of support, which allows less freedom for stable forward movement of body C of G. A longer step causes greater difficulty in advancing the body C of G into the support zone of the front foot, which in turn forces the groin muscles to play a major, and perhaps uncomfortable role in supporting body weight.

If the back knee is too high, the knees and hips tend to be prevented from flexing adequately, and the body C of G remains relatively high. This renders the base of support relatively narrower, and causes reduced stability both forward and sideways. A high back knee is often accompanied by an almost horizontal body posture that forces the adoption of an aiming point sufficiently near the mat to avoid neck discomfort that could result in aiming at a point further along the rink.

'Get the back knee well down, and body weight well forward'



In advancing one foot, bowlers must be careful to avoid placing the front foot on a line that narrows the separation between that of the back foot. The proper direction of advance forms a right angle with the original hip line. Any narrowing of the base of support could induce sideways instability as a side effect of avoiding forward or backward instability.

'Step straight without converging on the line of the back foot.'

Choice of Front (Leading) Foot, and Back (Anchor) Foot

Most bowlers advance the foot opposite the bowling arm. The minority who advance the foot adjacent to the bowling arm include some bowlers with disabilities that make that option more comfortable, or more controllable. One might speculate about why a right hand player ought not to step off with the right foot to reduce hip rotation. In a forward position, the adjacent foot may obstruct the delivery hand and bowl, and be likely to cause bowlers to make contact with their shoe or ankle unless they intuitively widen their delivery line. With the opposite foot forward, the hips – which may be quite wide - have rotated and narrowed their effective width helpfully, enabling a delivery line closer to the mid line of the body. Bowlers may then release their bowl under the body C of G, thereby minimising sideways instability. With the opposite foot forward, bowlers can then position their eye line or sighting line more readily over the delivery line.

Sideways Positioning Of Back Knee

If the front foot is directly in front of its corresponding hip to enhance stability, one might speculate that the hips and body would be squarer with the back knee positioned in front of its corresponding hip, than if the back knee is near the heel of the front foot. Some sideways freedom of movement of the back knee can positively enhance sideways stability. Any instability towards the left can be neutralised by intuitively swinging the back knee to the left. Opposite sideways instability may be neutralised by intuitive movement of the knee to the right. Anchoring the back knee against the heel of the front foot could negate such adjustments of body balance.

Placement of the back knee near the front heel, though turning the hips slightly out of a squared alignment can enhance dynamic stability. In this posture, the horizontal back leg angles from back ankle towards the front ankle. The bowling hand swings over and obliquely across the calf and passes very close to the inside of the front shoe. Bowl release occurs virtually under the body C of G, and under the aiming line. This technique tends to reduce the 'leverage' of destabilising forces.

Position of the Opposite (Non-bowling) Hand and Arm

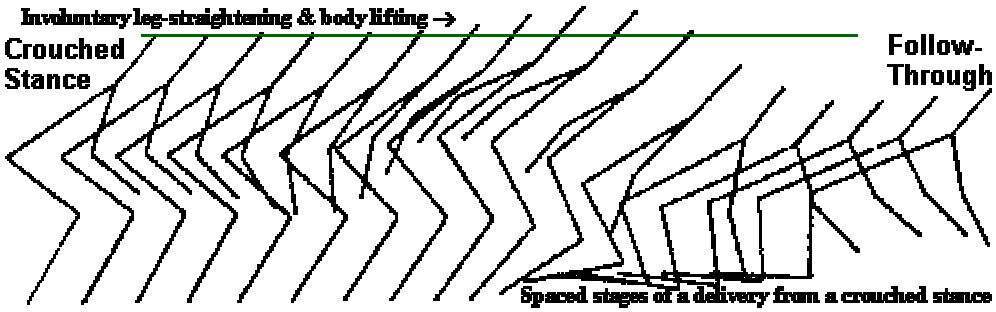
Once the legs provide a stable base of support for bowl delivery, that stability can be extended to the shoulder girdle by anchoring the non bowling arm near the front knee and using that arm as a brace. The hand or forearm can rest near the front knee. If it is too rigid, the non-bowling shoulder might be propped up, so tilting the shoulder line. It could also prevent adequate trunk inclination and adequate forward movement of the body C of G.

Crouched Delivery Posture

Some bowlers favour a crouched posture in preparing for bowl delivery. The crouch is equivalent to the *demi-plié* in dancing. Because it puts considerable stress on hip, thigh and calf muscles, it is generally unsuited bowlers without good muscle tone.

'Crouching deliveries are hard work'

Many bowlers who use a crouch are unable to take a pace immediately forward from that posture. The muscular strength in the 'back' leg is insufficient to support body weight while the opposite leg executes a forward pace. To relieve muscular tension, such bowlers intuitively execute a *relevé* (another dancing term, which simply means they partly straighten their legs) before starting a forward pace. The head and body of many of the crouching bowlers rises several inches as they begin a delivery movement. These supplementary movements all add to a bowler's co-ordinating task and contribute nothing to generating bowl delivery speed or controlling delivery line.



Extension of Bowling Arm

When preparing for a delivery, bowlers should avoid rigidly extending their arm forward. The weight of the bowl at the end of the arm represents a considerable moment of force that shoulder muscles can only support through third-class leverage. Such repetitive straining of shoulder muscles can lead to injury. The upper arm avoids most strain if nearly vertical and if the elbow is near the waist. The elbow may be flexed to allow the forearm to extend forward, yet avoid any feeling of strain or discomfort.

Recommended Bowl Delivery Procedure

Ordered List of Elements of A Delivery Movement

The following list sets out the sequence of elements of a delivery movement in lawn bowling. Usage of the terms 'left' and 'right' is valid for right-handed bowlers.

Preparatory Positioning
- Well-practised mat laying procedure
- Right foot along delivery line
- Left foot slightly separate but parallel
- Toes about 10cm behind front of mat

Grip
- Middle finger centred on running sole
- Bowl rings upright and aligned
- Right thumb near shoulder of large ring
- Bowls suitable size & grip comfortable

Stance
- Shoulders square to delivery line
- Right arm sufficiently elevated
- Right arm extended along delivery line
- Left hand not drawing right arm off square
- Knees comfortably flexed
- Weight over balls of feet
- Shoulder line forward of toes
- Attention directed forward

Delivery Movement
- Right arm unflexed during pendulum swing
- Left heel lifts as right arm passes hip
- Left foot advances parallel to delivery line
- Left foot advances a normal walking pace
- Sufficient amount of back swing
- Left heel grounds as forward swing starts
- Left foot settles parallel to aiming line
- Forward swing smoothly accelerates
- Right knee moves to position behind left ankle
- Left hand moves to left knee
- Attention still directed forward
- Bowl released at lowest point of swing
- At least 90% of weight over left foot
- Shoulders forward, above left knee

Follow Through & Recovery
- Right arm extended along line, palm upward
- Attention focused on moving bowl
- Recovery separated from follow through
- Steps forward off mat

General Recommendations

Like putting in golf, delivering lawn bowls does not require maximal speed, so a variety of techniques are capable of providing results of comparable accuracy. Some diversity is apparent in the delivery techniques of elite-level bowlers. Good technique reflects practiced fluency, simplicity, efficiency, consistency and accuracy. It avoids extraneous movements, each of which unnecessarily adds to the coordinating demands placed on bowlers.

'Keep it simple'

The instruction of novices initially requires reference to a model of sound technique. As they acquire experience and skill, developing bowlers may depart from that model. Such departures represent unorthodoxy rather than error, unless they clearly diminish the accuracy of results.

'Unorthodoxy is not error'